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AN AIR QUALITY ASSESSMENT  
OF COLSTRIP, MONTANA, PRIOR  
TO DEVELOPMENT OF COAL-FIRED POWER PLANTS

STATE DOCUMENTS

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Conducted By --  
The Montana Department of Health  
and Environmental Sciences  
Environmental Sciences Division  
Air Quality Bureau  
Helena, Montana

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Report Prepared By  
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AN AIR QUALITY ASSESSMENT  
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## I. INTRODUCTION

### A. Proposed Development

In March, 1973, the Montana Department of Health and Environmental Sciences (DHES) approved a permit for the Montana Power Company and Puget Sound Power and Light Company to construct two 350 mw coal-fired power plants (Colstrip Units 1 and 2) near the town of Colstrip, Montana.\* On June, 1973, the Montana Power Company, Puget Sound Power and Light Company, Portland General Electric Company, Pacific Power and Light Company and Washington Water Power Company applied for permission to construct two additional 700 mw coal-fired power plants (Colstrip Units 3 and 4) for the same area. The area of the planned development is characterized by very sparse population with the majority of the people engaged in ranching or farming. Very little actual industry of any size is operated in the area. The closest industrial center is Billings, Montana, some 100 miles west or Miles City, Montana, some 60 miles northeast (see map - Figure 1). The only sizeable development in the area has been the operation of coal strip mines.

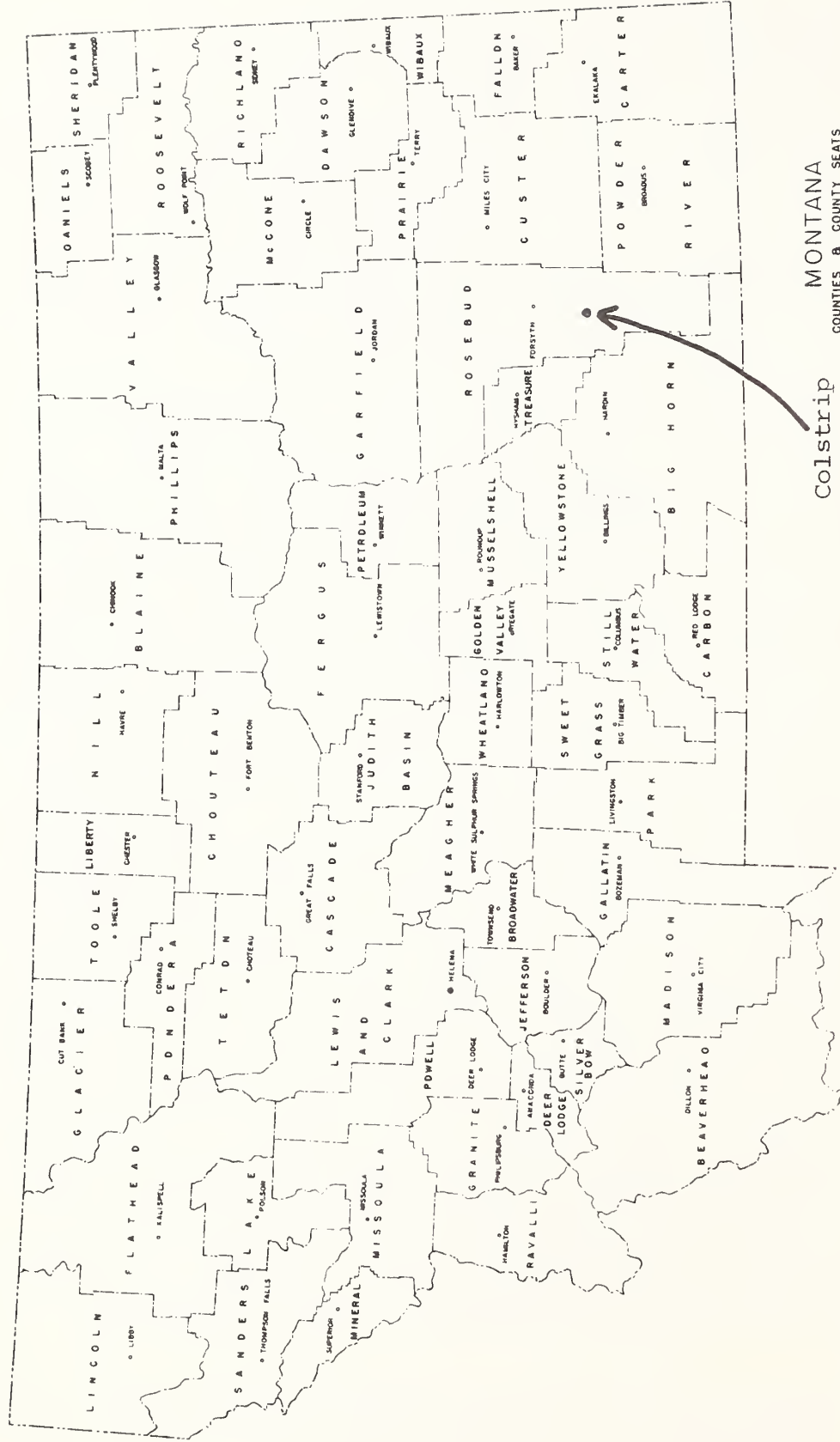
Located in the rolling hills of southeast Montana, Colstrip is some 28 miles south of the Yellowstone River and 10 miles or so west of Rosebud Creek. Except for the area to the southwest and west, the country is rolling hills covered by grass and sagebrush and an occasional area of small pine trees. The country slopes to the north and east into the Yellowstone River and Rosebud Creek drainages. A few miles to the southwest and west, the elevation increases to 4,000 feet, with the highest point, 4820 feet, some 15 miles west southwest of Colstrip. Sparse pines cover this area and increase in number and size with elevation.

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\*This report gives a general description of the Colstrip area and summarizes only that data collected by the DHES prior to startup of Colstrip Unit 1. This report does not attempt to summarize all the air quality and meteorological studies performed in the area. There are many on-going studies which will not be completed for some time.

Figure 1

Relative Location of Colstrip, Montana



Colstrip  
MONTANA  
COUNTIES & COUNTY SEATS

Scale 1 inch = 66 miles

## B. Climate

Climatological data provided by the U.S. Weather Service is summarized in Table 1. These data are means and extremes for the period 1941-1970 (except where noted). Table 2 summarizes similar climatological data collected by the Montana Department of Health and Environmental Sciences over the period January, 1974 - December 1974.

Comparison of the two tables shows close correlation between temperature averages. Degree days are somewhat different as the DHES data contains fewer days and therefore less degree days. Relative humidity readings at Colstrip from the DHES instrument were higher than expected.

The average annual precipitation for the Colstrip area is 15.79 inches of which three-fourths falls during the April-September growing season. This is 2 to 3 inches more than the lower elevation areas along the Yellowstone River and just slightly less than the annual precipitation at Lame Deer, a few miles to the south and at a slightly higher elevation. Almost six inches of precipitation falls during the early part of the growing season when the moisture supply is most important to the vegetation. Winter precipitation is generally light with just over a half-inch a month during the period November through February. Most of the precipitation during this time is in the form of snow. The average annual snowfall is only 34.6 inches. Heavy snowfalls are not common in this area and during the period 1946-1963 the greatest daily snowfall was just under 10 inches in December of 1958. Somewhat greater daily snowfalls of a foot and a half or more can be expected in the Colstrip area during a typical transition storm in the spring or fall. March and April can produce as much snow as the colder winter months, and as Table 1 shows the maximum monthly snowfall occurred in April, 1955.

Spring and fall are transition seasons between the cold of winter and the warmth of summer, and day to day changes can be large--particularly in late fall and early spring. In fact, it is this capacity for large changes within a day or less than produced the most troublesome type storm in about one in five years in the Colstrip

TABLE 1

U. S. DEPARTMENT OF COMMERCE  
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION  
ENVIRONMENTAL DATA SERVICE  
IN COOPERATION WITH COOPERATIVE EXTENSION SERVICE

CLIMATOGRAPHY OF THE UNITED STATES NO. 20 - 24

LATITUDE 45° 53'N  
LONGITUDE 106° 36'W  
ELEV. (GROUND) 3,221 ft.

## CLIMATOLOGICAL SUMMARY

STATION

MEANS AND EXTREMES FOR PERIOD 1941-1970

Month	Temperature (°F)				**	Precipitation Totals (Inches)				Mean number of days							
	Means			Extremes		Mean degree days	Year	Greatest daily	Snow, Ice Pellets				Precip. 10 inch or more	Temperatures		Year	
	Daily Maximum	Daily Minimum	Monthly						Record highest	Record lowest	Year	Mean		Maximum monthly	Year		Greatest daily
(a)	30	30	30	30	20	30	30	1943	30	30	1943	5.8	11.7	30	18	1946	
JAN.	34.2	7.7	21.0	67	1356	.56	.62	1943	5.8	11.7	1943	5.8	11.7	1943	5.5	1946	
FEB.	39.8	13.9	26.9	70	1053	.56	.55	1965	5.8	11.7	1955	5.8	11.7	1955	5.0	1959	
MAR.	45.8	18.9	32.3	80	1001	.74	.95	1943	6.0	13.9	1942	6.0	13.9	1942	5.0	1954	
APR.	59.3	30.1	44.7	87	624	1.86	2.82	1969	5.1	13.9	1955	5.1	13.9	1955	8.0	1963	
MAY	69.2	39.4	54.3	96	319	2.47	2.15	1946	+	3.0	1953	+	3.0	1953	2.0	1954	
JUNE	77.6	47.7	62.7	102	105	3.31	3.77	1944	+	3.0	1951	+	3.0	1951	8.0	1951	
JULY	89.2	53.8	71.5	107	12	1.18	1.33	1962+	0	0	----	0	0	----	0	----	
AUG.	88.1	52.1	70.1	111	24	1.39	1.83	1964	0	0	----	0	0	----	0	----	
SEP.	75.9	42.0	59.0	102	203	1.04	1.88	1945	+	7.0	1950	+	7.0	1950	7.0	1950	
OCT.	64.8	32.4	48.6	94	500	1.04	2.07	1958	2.0	13.1	1942	2.0	13.1	1942	8.0	1946	
NOV.	47.5	21.1	34.3	79	915	.67	1.18	1957	3.1	14.3	1941	3.1	14.3	1941	8.0	1957	
DEC.	38.2	12.8	25.5	71	1202	.63	.58	1958	6.8	15.4	1964	6.8	15.4	1964	9.5	1958	
Year	60.8	31.0	45.9	111	7314	15.79	3.77	JUNE 1944	34.6	19.0	DEC. 1955	34.6	19.0	DEC. 1958	9.5	1958	
Year																	

(a) Average length of record, years.

+ Also on earlier dates, months, or years.

T Trace, an amount too small to measure.

\* Less than one half.

\*\* Base 65°F

Greatest daily snow for period 1946-1963

TABLE 2

## HYGROTHERMOGRAPH DATA

McRae Site  
1974

MONTH	Aver. Temp.		Extremes		Degree Days		Rel. Hum.				Days Max Temp		Days Min Temp			
	Daily Max. Min.	Monthly	Hi	Date	(Temp)	Date	Heating	Cooling	HR	HR	HR	HR	90° & Over	32° & Over	32° & Below	
Jan	42	27	34	51	17	11	6	395	0	87	80	74	84	0	1	11
Feb	41	23	32	55	26	14	1	663	0	90	78	63	85	0	2	20
Mar	45	27	35	62	27	10	19	627	0	88	74	68	88	0	3	16
Apr	54	36	45	80	25	23	4	470	2	93	79	60	80	0	0	7
May	56	37	46	76	26	29	13	408	0	94	72	65	85	0	0	2
June	74	50	63	94	19	33	1	134	70	94	67	54	78	2	0	0
July	87	61	74	93	22	53	12	0	209	82	59	44	63	10	0	0
Aug	79	55	66	97	6	47	15	48	85	71	47	36	53	3	0	0
Sept	73	48	60	90	26	36	13	90	14	76	44	36	56	1	0	0
Oct	72	46	58	84	16	33	14	97	4	75	47	40	60	0	0	0
Nov	36	16	25	45	31	10	29	201	0	66	54	42	57	0	2	5
Dec	38	22	30	50	8	10	23	956	0	60	52	47	55	0	4	27
YEAR	59	39	49	97	-	10	-	4089	384	82	63	53	71	16	12	88

\*\*\*Averages, degree days and days max and min temp are based on days with 20 or more hours data.

\*\*\*Degree day is defined as the daily average temp - 65 where negative values indicate heating days.

\*\*\*Relative humidity values are averages of the relative humidity at the hour indicated over the entire month.

\*\*\*Range limits of instrument are from 10 to 110 deg F and 0 to 100 percent RH. Data outside these limits are considered invalid and eliminated.



area. Characteristically, a day preceding such storm may be very warm and windy for the season, followed by the onset of rain becoming progressively colder until wet snow appears.

Summer precipitation almost always occurs as showers, but late spring sometimes produces general rains of several hours in duration, and late September and October sometimes have rainstorms of the same general character. Thunderstorms are fairly common in the general area, probably occurring about 20 or 30 days a year. Showers with these storms can be quite intense but usually do not last long. Hail and strong winds occasionally occur, but not often. No tornadoes have been observed in Rosebud County over the past 20 years, but this may be partially due to the sparse population of the county. Other surrounding counties have observed tornadoes during this time, but when they do occur they are generally short lived and much smaller than those of the midwest.

Summers are characterized by warm days, but most nights, even during mid-summer, cool down to 60° or less, so oppressive hot spells are not very common. Temperatures of 90° or more occur about 40 days each year from May through October. Most of the 90° temperatures occur in July and August. Temperatures of 100° or more occur about two days of the year in at least 3 out of 4 years. High humidity may occur in the vicinity of relatively brief rainstorms. The combination of high temperature and humidity is, on occasion, a problem but it rarely lasts more than two days and is not oppressive. Mornings during July and August are mostly clear and sunny, but by afternoon on most days cloudiness appears, occasionally accompanied by thunder and rain showers.

The area tends to be continental in climate and character and winters are cold, but as Table 1 shows, the coldness is not extreme. While minimum temperatures usually cool to 32° or less during the winter most winter afternoons warm to at least the middle thirties. An occasional cold spell will generate sub-zero temperatures, but these spells seldom last more than two or three days. The temperature rises

above zero at least two days out of three during the winter months. Wind is seldom strong during cold spells; the coldest portion of a cold wave usually finds the sky clear with a light north to east wind (1).

### C. Health Statistics

A major area of concern that has arisen for this area is the incidence of death from respiratory disease. A recent study completed by the Montana Department of Health and Environmental Sciences has shown that Rosebud County (Colstrip) has an incidence of death from respiratory disease 86% higher for all ages than the Montana average and 104% higher for ages 65 and over (Table 3). For asthma, emphysema, and bronchitis, the Rosebud County rate is 42% higher than the Montana average. Similarly for pneumonia, the Rosebud County death rate is 163% higher for all ages than the Montana average and 206% higher for ages 65 and over. One reason for concern with the proposed Colstrip units is that the above respiratory diseases can be aggravated by air pollution (2).

### D. Ambient Air Quality Standards

The ambient air quality standards adopted by Montana are summarized in Table 4. The federal ambient air quality standards are summarized in Table 5. As of January, 1975, the federal regulations for the prevention of significant deterioration became effective. These regulations allowed areas to be classified as one of three possible classes according to the amount of degradation of air quality allowed in the area. The class designated for an area allows development coming into the area a set increment in the air quality levels. The different classes are summarized in Table 6. Initially the entire country was classified as Class II. Each state was then given the authority to reclassify areas within the state to either Class I or Class III or remain as Class II. Montana as of yet has not reclassified any areas of the state, therefore, the entire state remains as Class II.

Table 3

## ROSEBUD COUNTY DEATH RATES AS COMPARED TO MONTANA DEATH RATES

1. Respiratory Diseases	Rosebud Co. Rate*	Level of Significance	Comparison to Montana Rate
a. All Ages	122.1	0.1%	86% higher
b. All Ages - Male	171.4	0.1%	93% higher
c. All Ages - Female	71.5		68% higher
d. Ages 65 and over	935.2	0.1%	104% higher
e. Ages 65 and over - Male	1329.1	1.0%	92% higher
2. Asthma, Emphysema & Bronchitis			
a. All Ages	32.1		42% higher
3. Pneumonia			
a. All Ages	80.3	0.1%	163% higher
b. All Ages - Male	114.3	0.1%	217% higher
c. Ages 65 and over	685.8	0.1%	206% higher
d. Ages 65 and over - Male	949.4	0.1%	233% higher

Data taken from 1969-1973 death certificates

\*Deaths per 100,000 population



Table 4

## Montana Ambient Air Quality Standards

Pollutant	Standard	Averaging Time
Suspended Particulates	75 ug/m <sup>3</sup>	Annual
	200* ug/m <sup>3</sup>	24-Hour
Sulfur Dioxide	0.02 ppm	Annual
	0.10 <sup>+</sup> ppm	24-Hour
	0.25 <sup>a</sup> ppm	1-Hour
Settled Particulates	15 T/mi <sup>2</sup> (residential area)	3-Month
	30 T/mi <sup>2</sup> (industrial area)	3-Month
Suspended Sulfates	4 ug/m <sup>3</sup>	Annual
	12 <sup>b</sup> ug/m <sup>3</sup>	--
Reactive Sulfur	0.25 mg SO <sub>3</sub> / 100 cm <sup>2</sup> /day	Annual
	0.50 mg SO <sub>3</sub> / 100 cm <sup>2</sup> /day	1-Month
Fluorides, Total in Air (as HF)	1 ppb	24-Hour
Fluorides (Gaseous)	0.3 ug/cm <sup>2</sup> /28 days	28-Days

<sup>b</sup>Not to be exceeded more than one percent of the time.

<sup>a</sup>Not to be exceeded for more than one hour in any four consecutive days.

\*Not to be exceeded more than one percent of the days in a year.

<sup>+</sup>Not to be exceeded more than one percent of the days in a 3 month period.

TABLE 5  
Federal Ambient Air Quality Standards

POLLUTANT	PRIMARY STANDARD	SECONDARY STANDARD
1. Sulfur Oxides	80 ug/m <sup>3</sup> (0.03 ppm) annual arith. mean 365 ug/m <sup>3</sup> (0.14 ppm) max 24 hr. conc. not to be exceeded more than once a year.	1300 ug/m <sup>3</sup> (0.5 ppm) max 3 hr. conc. not to be exceeded more than once a year.
2. Particulate Matter	75 ug/m <sup>3</sup> annual geom. mean 260 ug/m <sup>3</sup> max 24 hr. conc. not to be exceeded more than once a year.	60 ug/m <sup>3</sup> annual geom. mean*, 150 ug/m <sup>3</sup> max 24 hr. conc. not to be exceeded more than once a year.
3. Carbon Monoxide	10,000 ug/m <sup>3</sup> (9 ppm) max 8 hr. conc. not to be exceeded more than once a year.  40,000 ug/m <sup>3</sup> (35 ppm) max 1 hr. conc. not to be exceeded more than once a year	Same as primary  Same as primary
4. Photo Chemical Oxidants (corrected for NO <sub>2</sub> and SO <sub>2</sub> interference)	160 ug/m <sup>3</sup> (0.08 ppm) max 1 hr. conc. not to be exceeded more than once a year.	Same as primary
5. Hydrocarbons (corrected for CH <sub>4</sub> )	160 ug/m <sup>3</sup> (0.24 ppm) max 3 hr. conc. (6 to 9 a.m.) not to be exceeded more than once a year.	Same as primary
6. Nitrogen Oxides (as Nitrogen Dioxide)	100 ug/m <sup>3</sup> (0.05 ppm) annual arith. mean	Same as primary

\*To be used as guide in assessing State Implementation Plans

Table 6

## FEDERAL AREA CLASSIFICATIONS FOR SIGNIFICANT DETERIORATION REGULATIONS

Pollutant	Class I		Class II		Class III	
	Allowable Increase (ug/m <sup>3</sup> )		Allowable Increase (ug/m <sup>3</sup> )		Not to Exceed (ug/m <sup>3</sup> )	
Particulate Matter						
	Annual Geometric Mean		10		75	
	24-Hour Maximum		30		150	
Sulfur Dioxide						
	Annual Arithmetic Mean		15		80	
	24-Hour Maximum		100		365	
	3-Hour Maximum		700		1300	

Since the construction of Colstrip Units I and II had commenced prior to June, 1975, these units were not subject to the non-deterioration regulations. However, Colstrip Units 3 and 4 are subject to these regulations.

## II. AMBIENT AIR QUALITY MONITORING NETWORK

Prior to the application by the Montana Power Company and the four other companies for Units 3 and 4 at Colstrip, the DHES had carried out a rather general background monitoring program for the southeastern Montana area. This study included measurement of such pollutants as total suspended particulates, fluorides, total dustfall and sulfation rate (related to sulfur dioxide concentrations). Upon application for Units 3 and 4, the DHES instituted a much more intensive ambient air monitoring program centered more at the Colstrip area. This study included the same parameters as in the general study above and in addition included sulfur dioxide, oxides of nitrogen, ozone, carbon monoxide, trace elements in the suspended particulates, visibility, ultraviolet and photosynthetic radiation, vegetation and trace elements in soil. Coincident with the DHES study was also an intense dispersion and air pollution potential study carried out by Montana State University (3).

The map (Figure 2) indicates the ambient air monitoring site locations for the initial study carried out by DHES. Figure 3 indicates the sites and location relative to the proposed plants for the recent more intense study. Tables 7 and 8 indicate the parameters measured at the respective sites.

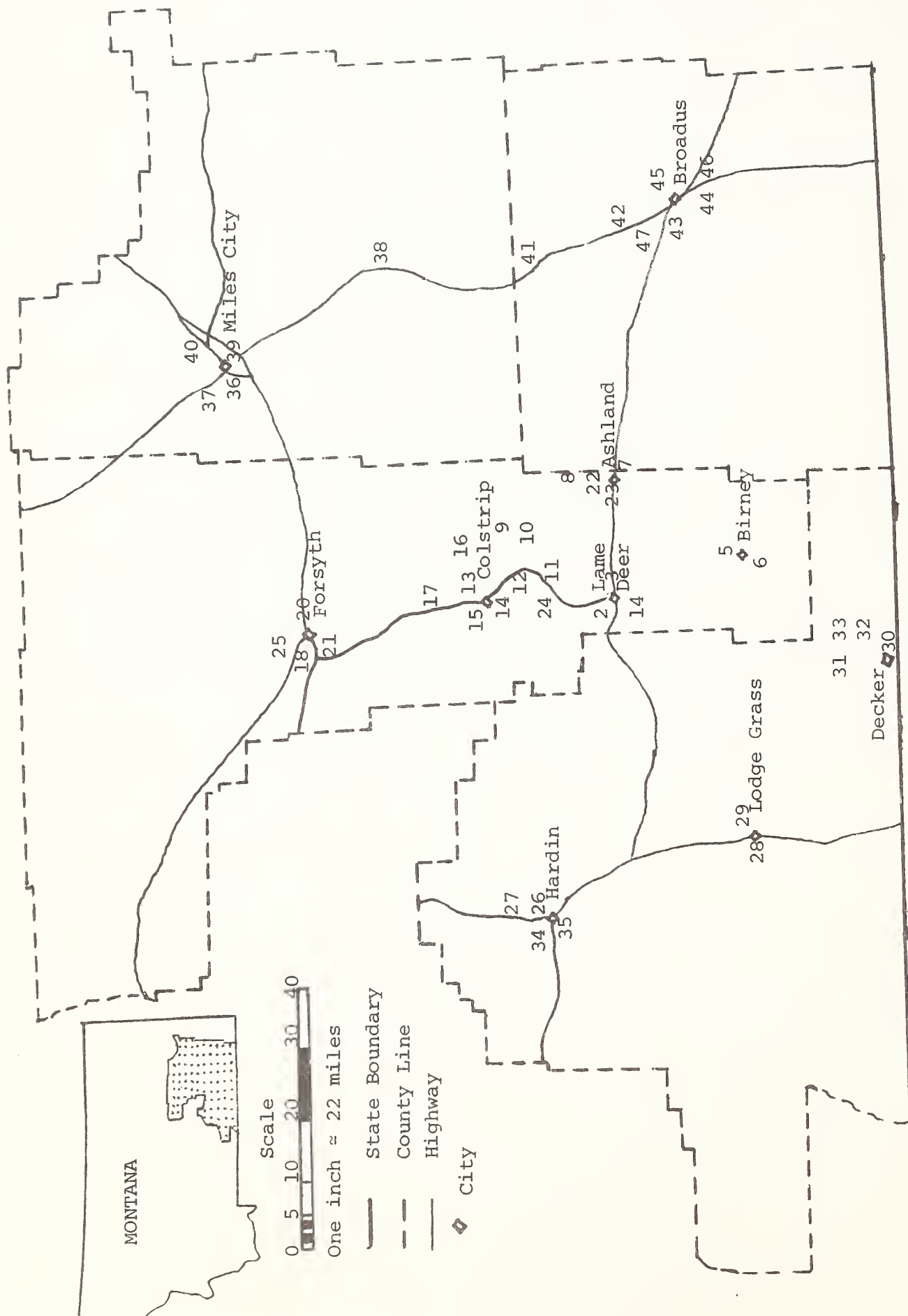


FIGURE 2

15  
BACKGROUND AIR QUALITY STUDY MONITOR LOCATIONS  
(Refer to Figure 2)

TABLE 7

<u>No.</u>	<u>Station</u>	<u>County</u>	<u>I.D. No.</u>	<u>Samplers*</u>
1	Lame Deer West	Rosebud	1360001	SN
2	Lame Deer N	"	1360002	SN
3	Lame Deer E	"	1360003	DSNCV
4	Lame Deer LDS Ch.	"	1360004	SN
5	Birney NE	"	1360005	DSNV
6	Birney SW	"	1360006	SN
7	Ashland E	"	1360007	SN
8	Ashland N	"	1360008	SN
9	Kluver Ranch	"	1360009	SNCH
10	Junction Station	"	1360010	DSNV
11	Colstrip S	"	1360011	SNV
12	Peabody E	"	1360012	DSNV
13	West Ener. Off.	"	1360013	SN
14	Water Tower	"	1360014	DSNCV
15	Warehouse	"	1360015	SN
16	Gun Club Station	"	1360016	SC
17	Oil Storage Tank	"	1360017	SN
18	Forsyth W	"	1360018	DSNV
19	Forsyth E	"	1360019	DSNV
20	Forsyth Depot	"	1360020	SN
21	Ira Gresons	"	1360021	SCCH
22	Ashland Power	"	1360022	DSNV
23	St. Labre Miss.	"	1360023	S
24	Bailey Ranch	"	1360024	H
25	Ferris Res.	"	1360025	H
26	Hardin East	Big Horn	0060001	SN
27	Radio Tower	"	0060002	DSNV
28	Lodge Grass W	"	0060003	SN
29	Lodge Grass E	"	0060005	DSNV
30	Decker Post Office	"	0060005	DSNV
31	Decker to Birney	"	0060006	SN
32	Decker Coal at Br.	"	0060007	DSNV
33	Carlot Ranch	"	0060008	DSNV
34	Hardin MDU	"	0680001	SC
35	Hardin West	"	0680002	SN
36	F & G Off.	Custer	0300001	DSNV
37	Gravel Pit N	"	0300002	SN
38	Volburg	"	0300003	DSNV
39	Asay's Res.	"	1040001	DSNVH
40	Miles City E	"	1040002	DSNV
41	Coalwood	Powder River	1240001	SN
42	Ash Creek	"	1240002	S
43	W. Broadus	"	1240003	DSNV
44	Broadus E	"	1240004	DSNV
45	Sewage Lagoon	"	1240005	SN
46	LaFlamme	"	1240006	SCCH
47	312-212 Jct.	"	1240007	S

\*S - sulfation rate

N - Na Formate Plate (F<sup>-</sup>)

C - Ca Formate paper (F<sup>-</sup>)

D - Dustfall

V - Vegetation (F<sup>-</sup>)

H - Hi-vol (Total suspended particulate)



FIGURE 3

Colstrip Area  
Rosebud County

Ambient Air Monitors

Map No.	Site Name
1	BN Site
2	McRae Site
3	Halfway
4	Antenna Hill
5	Sewage Lagoon
6	Colstrip West

Major Point Sources

Map No.	Source Name
A	Montana Power Co.

Scale: 1 inch = 2 miles

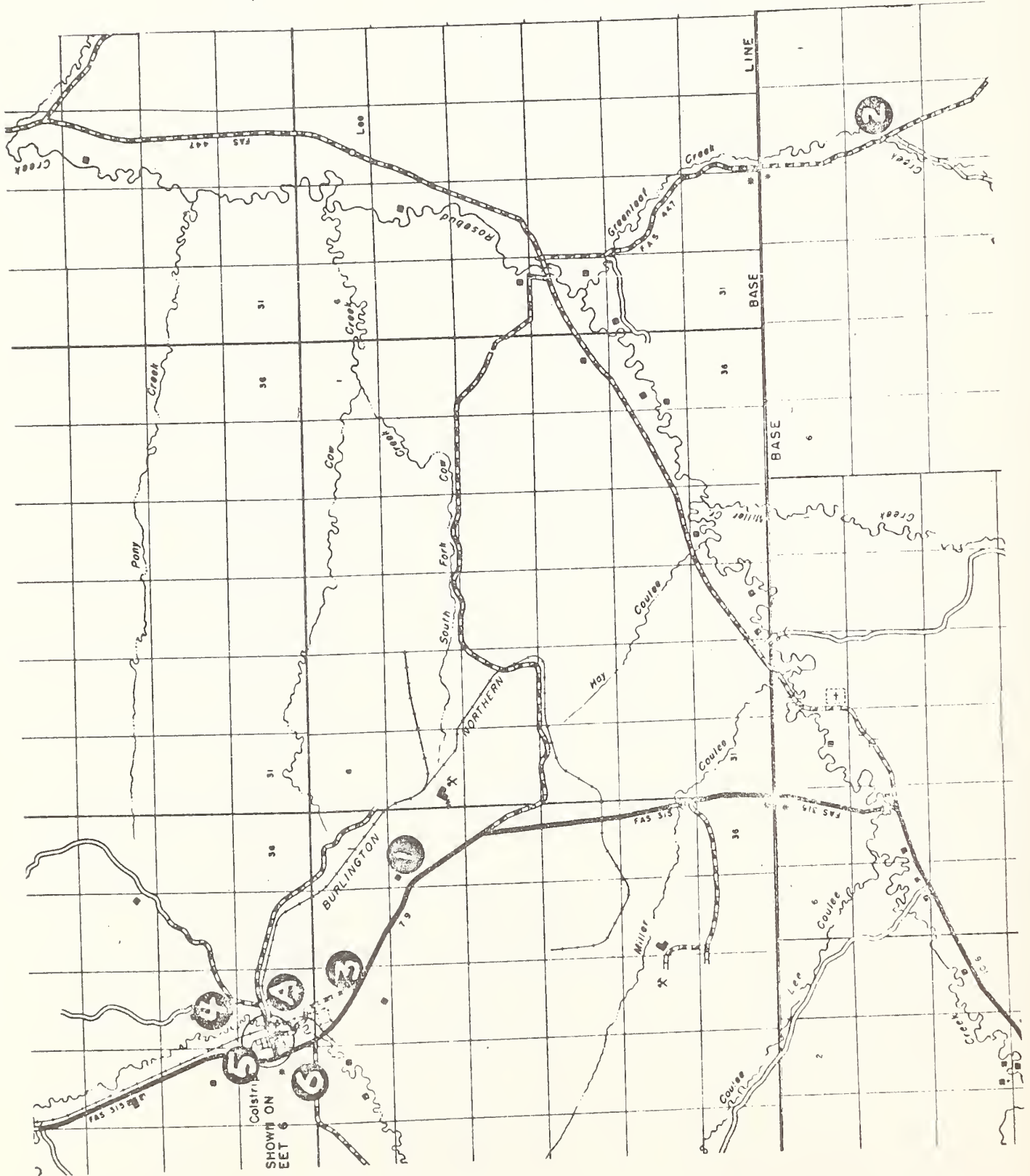




TABLE 8

## Colstrip Area Background Parameters Monitored

Parameter	Sites (Map No.)*	Sampler Type	Sampling Interval
Total Suspended Part.	1,2	Hi-Vol	24 hour
Trace Elements	1,2	Membrane	24 hour
Particle Size	1,2	Cascade	72 hour
Settled Particulates	1-4	Dustfall	Monthly
Sulfur Dioxide	1,2	Continuous	Continuous
Carbon Monoxide	2	Continuous	Continuous
Oxides of Nitrogen	1,2	Continuous	Continuous
Ozone	1,2	Continuous	Continuous
Oxidized Sulfate	1-6	Sulfation Plates	Monthly
Fluorides	1,2	Calcium Formate Papers	Monthly
Fluorides	1-4	Sodium Formate Plates	Monthly
Sulfur Dioxide	1,2	Bubbler	72 hour
Nitrogen Dioxide	1,2	Bubbler	72 hour
Ultra-Violet Radiation	2	Continuous	Continuous
Photosynthetic Radiation	2	Continuous	Continuous
Relative Humidity	2	Continuous	Continuous
Temperature	2	Continuous	Continuous
Wind Direction	1,2	Continuous	Continuous
Wind Speed	1,2	Continuous	Continuous

\* Map numbers corresponding to Figure 3



### III. SAMPLE COLLECTION AND ANALYSIS

#### A. Ambient Air Quality

In general particulate data was collected through the use of filtration process. High-volume samplers (See Appendix A for detailed descriptions) using glass fiber filters collected particulates to give indications of the total suspended particulate levels. Data as to the composition of suspended particulates was obtained through the use of cellulose membrane filters. These filters were used to detect trace elements in the air as the cellulose filters do not in general contain the trace metal contamination associated with the glass fiber filters. Data as to the size of suspended particulates was collected through the use of high-volume particle fractionating cascade impactors. These samplers use a series of glass fiber filters and separation plates with different aerodynamic properties to separate the suspended particulates into different size categories. The final particulate sampler did not use the filtration process. This sampler, simply called a dustfall bucket or jar, collected total settled particulates as opposed to suspended particulates for the previous three samplers. The dustfall bucket simply was a large pre-weighed jar allowed to stand in the open and collect the larger particles that settle from the air naturally.

Gaseous pollutants were measured by two general processes, continuous gas analyzers and gas bubblers. The continuous gas analyzers as the name indicates continually sample and analyze the ambient air. These samplers were used to measure sulfur dioxide, carbon monoxide, ozone and oxides of nitrogen. The gas bubblers were used to sample sulfur dioxide and nitrogen dioxide. The ambient air is drawn into a tube and bubbled through an absorbing solution at a premeasured rate for 72 hours. The solution is then analyzed in a chemistry laboratory for the pollutant level observed.

Indicator type samplers were used to measure sulfation rate and fluorides in the air. The samplers were of two forms. The first, sulfation plates and sodium

formate plates (used to measure fluoride), were small plastic petri dishes coated on the inside with reactive chemicals. The open dishes were then exposed to the ambient air for approximately one month and then chemically analyzed to determine the pollutant levels. The second indicator used was calcium formate papers (used to measure fluoride) which were filter papers impregnated with calcium formate and exposed to the ambient air in protective shelters for approximately one month. The filters were then chemically analyzed to determine the pollutant level.

Meteorological monitors were also used to measure atmospheric visibility, humidity, temperature, wind speed, wind direction, ultraviolet radiation and photosynthetic radiation. The visibility was measured continuously through use of an integrating nephelometer. Temperature and humidity were measured through the use of a hygrothermograph. Wind speed and direction were measured with mechanical weather stations. Ultraviolet radiation was measured using a UV radiometer while photosynthetic active radiation was measured using a continuous instrument manufactured by Lambda Instruments (use of a manufacturer's name does not constitute endorsement of the product).

#### B. Vegetation

Vegetation sampling was conducted along rivers, creeks and coulees in the Colstrip vicinity. Sampling was conducted to determine background levels of fluoride in the plants in the Colstrip area and in the Tongue River area east and southeast of Colstrip. Plants in the Tongue River area were sampled also to measure relative frequency, density, and dominance of plant species as well as estimated height and age of overstory and understory trees. Sampling was conducted in twenty-four sampling sites along the eight cardinal directions (i.e. N, NE, E, etc.) at distances of 5, 10 and 15 miles from the power plant in the Colstrip area. In the Tongue River area twenty control plots were established and samples taken. Chemical analyses as to fluoride levels were then performed in the laboratory.

### C. Soils

Soil samples were collected in May, 1974 using standard procedures recommended by soil scientists at Montana State University. A soil sampling corer was used to extract the soil cores. At each site eight cores were extracted at random within a small defined plot. Each core was separated into an A<sub>1</sub> and B<sub>2</sub> horizon. Corresponding horizons from these eight cores were mixed and a small compound sample for analysis was placed in a labeled plastic bag. Analysis was then performed in the laboratory for a series of trace elements.

### D. Quality Control

Calibration procedures were conducted routinely according to Environmental Protection Agency (EPA) guidelines. Quality control techniques were incorporated into the sample collection and service program as outlined by EPA also. The following is a general discussion by sampler of the methods used to insure quality of the data.

High-Volume Filter Collection. All filters were marked prior to exposure for identification. Instruments were calibrated prior to and after collection of sample to measure flow changes. Total volume of air flow was strictly logged with each filter. Filters were handled carefully and kept clean to avoid contamination. Filters were mailed in special sealed envelopes to avoid loss of collected material from the filters.

Continuous Monitors. The monitors were periodically calibrated. Drift in baseline was strictly logged and baseline drift over a 24-hour period greater than  $\pm 2\%$  invalidated the data. Only certified permeation tubes or span gases were used in calibrations.

Bubblers. Volume of sample used and the micrograms of pollutant sampled were strictly checked. Hypodermic needles used in sample collection were calibrated before and after sample collection. Samples were mailed in wooden protector boxes to avoid damage to samples.



Indicators. Ca formate papers were handled only by forceps or very clean hands and only by the very edges. When transporting, papers were enclosed in sterile plastic bags or glycine envelopes and sealed. In the laboratory analysis, with every eleven samples analyzed was an unexposed paper to detect contamination. The auto-analyzer was calibrated prior to every run.

As for Na formate plates, the sample was contained in a covered plastic petri dish before and after exposure. An unexposed plate was also run with exposed plates for detection of contamination. The instrument was calibrated prior to runs. Sulfation plates followed the same procedure as Na formate plates as far as quality control.

Dustfall measuring jars were covered prior to and after sample collection. Excessive interference to weighing such as bird droppings or insects in the buckets invalidated some samples.

Meteorological Data. Wind data was read from strip charts and any inconsistencies in the data were noted in a logbook by the technician. Any comments by the field technician as to the validity of the data were also noted. Temperature and relative humidity data followed the same procedures. The hygrothermograph was also periodically calibrated by an aspirated psychrometer. Nephelometer reading followed the same general procedure as the wind instrument. Calibrations were performed periodically. Solar radiation and ultraviolet radiation instruments required occasional washing and cleaning of the diffusion disc. Instruments were also checked to insure levelness. Processing of the data followed the same general procedure as previously mentioned instruments.

All chemical analyses were performed in laboratory facilities in Helena by DHES staff. All analyses methods used were considered state-of-the-art. A lab and field technician was located in Colstrip to routinely service and maintain all instruments. Rigid documentation of all service calls and calibration was maintained by the technician. Frequent reviews and checks of field procedures and instruments were made by personnel from the DHES office.

Most of the monitors were installed between November 1, 1973 and December 15, 1973. Calibration of the instruments was conducted prior to installation or within 1½ months after installation.

#### E. Data Reduction

Charts and samples collected at the various sites in the Colstrip area were routinely sent by mail or by vehicle to the Air Quality Bureau in Helena for analysis. Comments by the on-site technician were written on each chart as to the validity of the data. Also any circumstances in the weather that may have altered readings were reported. When charts were received at Helena, they were read and values were transferred directly to SAROAD forms (EPA standard forms for Storage and Retrieval of Aerometric Data). Any comments causing data to be questionable or periods when instruments were not working properly caused this data to be invalidated. Samples that were collected for laboratory analysis were marked when received and then sent directly to the laboratory.

After a month's data was recorded on the SAROAD forms, they were sent to the State Department of Administration, Data Processing Bureau, for keypunching and verifying. Following this the data was run through the State Department of Highways IBM Systems 370 computer with various programs. Computer programs were written by Air Quality Bureau personnel to be general enough to accept several different forms of data and yet present this data in a summary form that was meaningful. Data was also checked by the computer programs for errors in station code, dates, and sequence of the data. Following the summary by the computer programs, the printout sheets were examined for inconsistencies in the data or any other obvious errors. Any values that appeared questionable were verified either from laboratory records or from strip charts.





#### IV. DATA SUMMARY

##### A. Air Quality

The tables in Appendix B summarize the data collected in the studies performed by DHES at Colstrip. For the area of concern in the initial general study, the background data showed very low concentrations of all pollutants measured. Total suspended particulates were on the order of 15 to 30  $\mu\text{g}/\text{m}^3$  annual geometric mean. Some areas did measure higher concentrations but these were orientated toward a particular local source. Sulfation rates averaged 0.04 to 0.05 mg of  $\text{SO}_3/100 \text{ cm}^2/\text{day}$ . These values were well below the Montana ambient air standard of 0.25 annual average. Fluoride levels ranged from 0.00 to 0.05  $\mu\text{g}/\text{cm}^2/30 \text{ days}$  for annual concentrations, which were well below the 0.30 Montana ambient air standard.

The more intense ambient air quality study performed near Colstrip revealed the same relative concentrations of pollutants as the more general study. Total suspended particulate concentrations averaged around 15  $\mu\text{g}/\text{m}^3$ . Figure 11 of Appendix B shows the frequency of particulate concentrations for the two sites in a percentage distribution. Settleable particulates averaged 3 to 7 tons/square mile compared to the Montana standard of 15 tons/square mile. Fluoride concentrations were measured to be about 0.01  $\mu\text{g}/\text{cm}^2/30 \text{ days}$  which was also well below the Montana ambient air standard of 0.30. Sulfation rates followed the same pattern as the more general study with most stations recording even lower concentrations than the initial study. Continuous monitor and gas bubbler data showed essentially zero concentration of sulfur dioxide, oxides of nitrogen and carbon monoxide. Ozone was the only pollutant measured that approached the ambient air quality standards. The federal ambient air standard for photochemical oxidants (ozone) is 0.08 ppm for one-hour not to be exceeded more than once a year. The maximum one-hour concentration recorded at the McRae site was 0.08 ppm. The annual average was 0.03 ppm. The monitor was moved to the BN site in July, 1975, and two months of data was obtained from that site up to the cutoff for this report. This site had a measured one-hour

concentration of 0.06 ppm and an average concentration of 0.03 ppm.

The particulate concentrations were also analyzed using a cascade impactor for measuring particle size. Impactors were run at the BN and McRae sites. Results showed the BN site averaging higher particulate concentrations and also a higher percentage of large particles (7.0 microns and larger). This could have been affected by construction activity, strip mining in the vicinity and physical location of the BN site being closer to the town of Colstrip. The McRae site was probably, therefore, more characteristic of the true background ambient air quality. Trace elements in the air were also analyzed using membrane samplers. Many of the elements had concentrations less than the detectable limit of the analysis method used. Calcium and iron were found in the highest concentrations. Results for the twenty elements analyzed for are given in Appendix B.

## B. Vegetation

The tables summarizing the vegetation study are given in Appendix B. The plants found prevalent within the twenty sampling plots established along the Tongue River were identified using Hitchcock and Cronquist Flora of the Pacific Northwest (4). They were subsequently verified using the University of Montana Herbarium collection. Note that with forbs and grasses which were sampled no attempt was made to identify highly infrequent species which accounted for less than 1% cover of the plot area. The significance of each species was apparent upon studying the data in the tables of Appendix B. The columns indicating relative frequency, dominance, and density are most useful in characterizing the plant community. The Cottonwood (Populus deloides) was the dominant tree in the plant community with a relative dominance of 69.9 percent. Green Ash (Fraxinus pennsylvanica) rated second to Cottonwood in dominance followed by Boxelder (Acer negundo) and Willow (Salix). In terms of relative frequency both Cottonwood and Green Ash ranked equally with 24.4 percent. Boxelder and Willow ranked third and fourth with relative frequencies of 22.2 and 13.4 percent, respectively. Note that these figures hold

for the tree size class, dominated in sapling and seedling size classes. Willow which had a relatively low dominance in the tree size class (5.45%), had a dominance nearly four times as great in the sapling size class for the community. Comparing relative frequency of particular species across the tree, sapling and seedling classes, it is apparent that some species such as Boxelder remained fairly constant with relative percentages of 22.20, 23.50 and 18.18, respectively. Others such as Willow were far more frequent as a sapling than as a tree. Cottonwood ranked first in stand density (29.3%) followed by Chokecherry (22.7%), Ash (20.0%) and Boxelder (14.0%). Again this ranking held in the tree size class but was not true in either the sapling or seedling size class. For instance Chokecherry had a relative density of 20.52% in the sapling size class while being entirely absent from the seedling size class. Within the shrub size class Prairie rose (Rosa arkansana) and Snowberry (Symphoricarpos ollidentalis) were most frequent. Rose dominated this size class with a relative dominance of 65.26%. Snowberry ranked second in dominance with a relative percentage of 20.08. Both of these two species ranked equally in terms of density.

In addition to the above stand parameters, determinations of tree heights and ages were made. The overstory was dominated by Cottonwood with an average height of 52.2 feet. The other tree found in the overstory was Willow, however, its mean height (29 feet) would not reflect this as being overstory. This was due to large deviations from the mean. The understory trees of this community included Ash, Boxelder, Willow and Chokecherry with mean heights of 38.8, 33.6, 29.0 and 21.2 feet, respectively. Hawthorn with a density of 2.7 was a relatively infrequent member of this understory community.

The borings for tree ages were limited to trees having modest diameters so that these ages are much less than that of large dominant Cottonwoods, for example, having diameters of up to 35 inches. The largest overstory tree sampled, a Cottonwood, was determined to be 56 years old. This particular tree had a diameter at breast height of 10.5 inches. The ages of Ash, Boxelder, Chokecherry and Willow

were more representative since they covered the entire range of diameters recorded for these species in the Tongue River sampling plots.

Results from fluoride analyses for the Tongue River and for the Colstrip vegetation samples included nine representative species. These include: Boxelder, Hawthorn, Green ash, Cottonwood, Chokecherry, Golden currant, Prairie rose, Snowberry and Willow. Fluoride levels in the samples were measured down to 0.1 ppm, the limit of the analysis method.

The majority of samples collected in the twenty Tongue River plots had a fluoride level less than 0.1 ppm. A peak concentration of 15 ppm was found in a Chokecherry sample. Standard deviation from the mean and the arithmetic mean were tabulated for each species and each plot. Cottonwood and Prairie rose contained the lowest mean fluoride concentration of the nine species sampled. These two species also had the smallest standard deviation. The high standard deviation present in the fluoride levels of Boxelder, Chokecherry, Snowberry and Willow reflects the great variation in fluoride found among these samples. The fluoride variation should not be restricted solely to individual plant differences, however, since each sample was a compound sample taken from all plants of the particular species within the sampling plot.

The mean levels of fluoride from the sample plots showed great variation. The levels ranged from 0.05 ppm to 3.52 ppm fluoride for the plots. There was also wide variation in the plot fluoride standard deviation indicating differences in species and plot location.

The levels of fluoride were also measured in vegetation samples from sites located on radii in the 8 cardinal directions radiating from Colstrip. The same species were sampled on these plots as on the Tongue River plots. Here Cottonwood and Snowberry contained the least amount of fluoride with 0.47 ppm and 0.43 ppm, respectively. The highest fluoride concentration within these samples was found in Willow. Willow also had a high standard deviation as did Boxelder and Prairie rose. Again since



each sample reported was a compound sample these deviations probably reflect differences between plots rather than differences between plants. The lowest mean plot fluoride levels were found in the three plots located north of Colstrip plant. All the samples taken fell within the range of background fluoride levels of 10 ppm. Therefore, none of the samples appeared abnormal in fluoride content. Considering the level of fluoride found in the soil samples of the Colstrip vicinity it became apparent that the plants select against fluoride in absorption of minerals.

### C. Soils

Soils of southeastern Montana are azonal in nature. Such soils are characteristic of dry grasslands of semi-arid regions of the United States. These soils are classified within the chestnut and brown soil groups. Due to the lack of heavy rainfall, they are quite low in organic matter (5). Their surface layers are characteristically neutral or even alkaline. Profile development of these soils is less marked and organic matter content more scanty than with other soils. The characteristic soils profile in this area has only an A<sub>1</sub> and B<sub>2</sub> horizon within a depth of 18-20 inches. The A<sub>1</sub> horizon contains organic matter thoroughly mixed with inorganic material. The B<sub>2</sub> horizon has a high concentration of minerals leached from the A<sub>1</sub> horizon, especially iron and aluminum. A clay accumulation also may be evident. Below these horizons is a calcium carbonate layer which inhibits drainage and helps prevent leaching of the organic material from the soil above.

Results of the soil analyses are included in Appendix B. Included are data on twenty-two elements plus pH (measure of acidity or alkalinity) determinations. The pH data indicated a typical alkaline pH expected in chestnut soils (5). The pH of the A<sub>1</sub> horizon was significantly less alkaline than the pH of the B<sub>2</sub> horizon.

The trace elements found in highest concentration in the soil included iron, calcium, potassium, magnesium, sodium, fluoride and manganese, in that order. Arithmetic means and standard deviations were tabulated for each element. An examination of the data showed tremendous variation among some of these elements. This agrees with

expectations for soil samples taken in areas of different aspect and vegetative cover. Trace elements such as selenium, antimony, beryllium, silver and cadmium show much less variation from site to site. With the trace elements tin and lead the concentrations were below the detectability limits of the method. There were no consistent trends between the concentration of elements found in the upper and lower soil horizon. This was true despite the findings with the soil pH.

The high concentration of sodium, potassium, calcium, magnesium and iron found in the samples is consistent with the importance of these elements in soil minerals (5). Both magnesium and calcium are found in typically high concentration in arid soils. The order of concentrations of potassium, calcium and magnesium in arid soils is expected as potassium > calcium > magnesium. With the samples taken by DHES this held true for calcium and magnesium but not with potassium.

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APPENDIX A  
DETAILED SAMPLE COLLECTION  
AND ANALYSIS



## A. Air Quality Monitors

1. High-Volume Sampler. Tables 9 and 10 indicate all of the background parameters monitored by the DHES during the background air quality study. Table 10 also includes other information as to the sampling frequency, estimated accuracy, and analysis methods. The high-volume sampler was used to sample suspended atmospheric particulate pollutants. The principal of collection was filtration of suspended particulates (suspended particulates being those particles which tend to remain in the atmosphere for extended periods of time). Specific particle size fractions sampled cannot be defined by this method. However, by employing Stoke's law and using an average gas velocity, it can be found that this type unit, housed in a shelter will sample under quiescent conditions particles to 100 microns in diameter having a specific gravity of 2.65 and average velocity of 64 feet per minute across the horizontal air inlet portal of the shelter. Wind will upset this relationship and allow collection of larger and heavier solids.

A typical hi-vol is shown in Figure 4. A vacuum sweeper motor pulled air through a glass fiber filter which offers high filtering efficiency for submicron particles with minimum pressure drop throughout the sampling period with limited water absorption from the air.

Prior to use, each filter was serialized and precision weighed under laboratory conditions. The filter was shipped to the sampling site where ambient air was drawn through it for 24 hours. A calibrated field-type rotameter reading was made before and after the 24-hour sample was taken. The average of these two air flow rates was used to find the total volume of air which had passed through the sampler. The filter was returned to Helena where it was equilibrated at laboratory conditions before a second precision weighing was made. This difference in weight along with the total volume of air drawn through the device in 24 hours gave the total suspended particulate loading in micrograms per cubic meter of ambient air.

The primary advantage of the hi-vol is that it will sample a large volume of

TABLE 9

Parameter	Instrumentation Method	Instrument Manufacturer	Sampling Period
Sulfur Dioxide	Coulometric	Phillips	Continuous
Sulfur Dioxide	West Gaeke Bubbler	Misco	72-hr.
Nitric Oxide	Chemiluminescence	Bendix	Continuous
Nitrogen Dioxide	Chemiluminescence	Bendix	Continuous
Oxides of Nitrogen	Chemiluminescence	Bendix	Continuous
Nitrogen Dioxide	Kristi Bubbler	Misco	72-hr.
Ozone	Chemiluminescence	Bendix	Continuous
Carbon Monoxide	Infra-red	Bendix	Continuous
Suspended Particulate	Hi-Vol	Anderson 2000	24-hr.
Suspended Particulate Sizing	Cascade Impactor	Anderson 2000	48-hr.
Settled Particulate	Dustfall	(dept.)	1 month
Sulfates	Lead Peroxide	(dept.)	1 month
Fluorides	Sodium Formate	(dept.)	1 month
Fluorides	Calcium Formate	(dept.)	1 month
Trace Metals	Membrane Sampler	Research Appliance	24-hr.
Wind Direction	Mechanical	MRI	Continuous
Wind Speed	Mechanical	MRI	Continuous
Temperature	Bimetal	MRI	Continuous
Visibility	Nephelometer	MRI	Continuous
Relative Humidity	Hair Hygrometer	Belfort Inst.	Continuous
Temperature	Bimetal	Belfort Inst.	Continuous
UV Radiation	Photometer	Eppely	Continuous
Photosynthetic Radiation	Quantum Sensor	Lambda	Continuous
Fluorides	Vegetation	(dept.)	Seasonal

TABLE 10

## Background Parameters Monitored

Parameters	Units	Sampling Interval	Number of Monitors	Sites	Est. Accuracy Limits	Analysis Method
Total Suspended Part. (0.01 - 100 $\mu$ )	ug/m <sup>3</sup>	24 hr.	2	B.N. & McRae	$\pm 1$ ug/m <sup>3</sup>	Chem & Gravimetric
Settled Particulates ( $\geq 50\mu$ )	tons/mi <sup>2</sup>	monthly	4	B.N., McRae, Antenna Hill, Halfway	$\pm 50\%$	Gravimetric
Particulate Size (.01 $\mu$ - 50 $\mu$ )	ug/m <sup>3</sup>	72 hr.	2	B.N. & McRae	$\pm 1$ ug/m <sup>3</sup>	Gravimetric
Trace Elements (Particulate .01 $\mu$ - 50 $\mu$ )	ug/m <sup>3</sup>	24 hr.	2	B.N. & McRae	$\pm 10\%$	Chemical
Visibility (Particles 0.01 - 2 $\mu$ )	Miles	Continuous	2	B.N. & McRae	$\pm 10\%$ of scale	Light Scattering
Oxidized Sulfates (Gaseous Sulfur Compounds)	mg SO <sub>3</sub> /100 cm <sup>2</sup> /day	monthly	6	B.N., McRae, Sewage Lagoon, Colstrip West, Halfway, Antenna Hill		Turbidimetric
Sulfur Dioxide (SO <sub>2</sub> )	ppm	continuous	1	McRae	$\pm .01$ ppm	Coulometric
Sulfur Dioxide (SO <sub>2</sub> )	ppm	72 hr.	2	B.N. & McRae		Modified West-Gaeke
Nitrogen Oxide (NO)	ppm	continuous	1	McRae	$\pm .01$ ppm	Chemiluminescence Photometric
Nitrogen Dioxide (NO <sub>2</sub> )	ppm	continuous	1	McRae	$\pm .01$ ppm	Chemiluminescence Photometric

TABLE 10 (Cont.)

Parameters	Units	Sampling Interval	Number of Monitors	Sites	Est. Accuracy Limits	Analysis Method
oxides of Nitrogen (NO <sub>x</sub> )	ppm	continuous	1	McRae	± .01 ppm	Chemiluminescence Photometric
Nitrogen Dioxide (NO <sub>2</sub> )	ppm	72 hr.	2	B.N. & McRae		Kristi
Ozone (O <sub>3</sub> )	ppm	continuous	1	McRae	± .001 ppm	Chemiluminescence
Carbon Monoxide (CO)	ppm	continuous	1	McRae	± .3 ppm	Non-Dispersive Infrared
Sulfur Dioxide (Sulfurous F)	ug F <sup>-</sup> /cm <sup>2</sup> /30 day	monthly	2	McRae & B.N.	± 10%	Chemical
Sulfur Dioxide (Gaseous F)	"	Monthly	4	McRae, B.N., Anna Hill, Halfway	± 10%	Chemical
Sulfur Dioxide in Vegetation	ppm	seasonal	32	See Sec. 11.1.6, 2.B.d	± 10%	Chemical
Sulfur Dioxide in Soils	ppm	annual	32	"	± 10%	Chemical
Ultra-violet Radiation (259 - .385μ)	mcal/cm <sup>2</sup> /min	continuous	1	McRae	± 2%	Photometric
Photosynthetic Active Radiation (.4 - .7μ)	μEinstains/m <sup>2</sup> /sec.	continuous	2	2 - McRae	± 1%	Photochemical
Relative Humidity	percent	continuous	1	McRae	± 5%	Mechanical
Temperature	OF	continuous	3	2-McRae, B.N.	± 30F	Mechanical
Wind Direction	° from N	continuous	2	B.N., McRae	± 1%	Mechanical
Wind Speed	miles/hr	continuous	2	B.N., McRae	± 2%	Mechanical



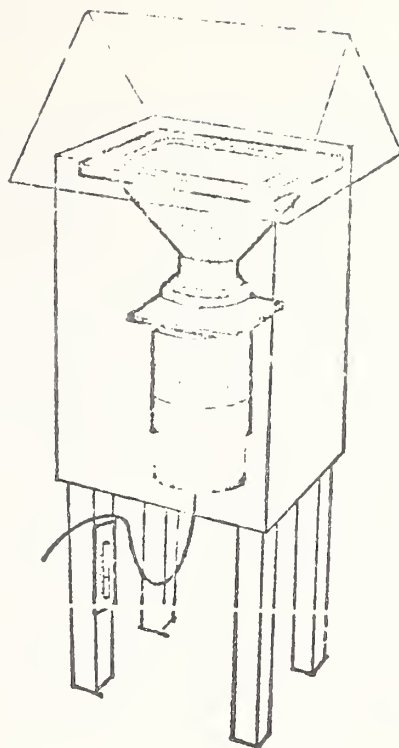


Figure 4 High-Volume Particulate Sampler

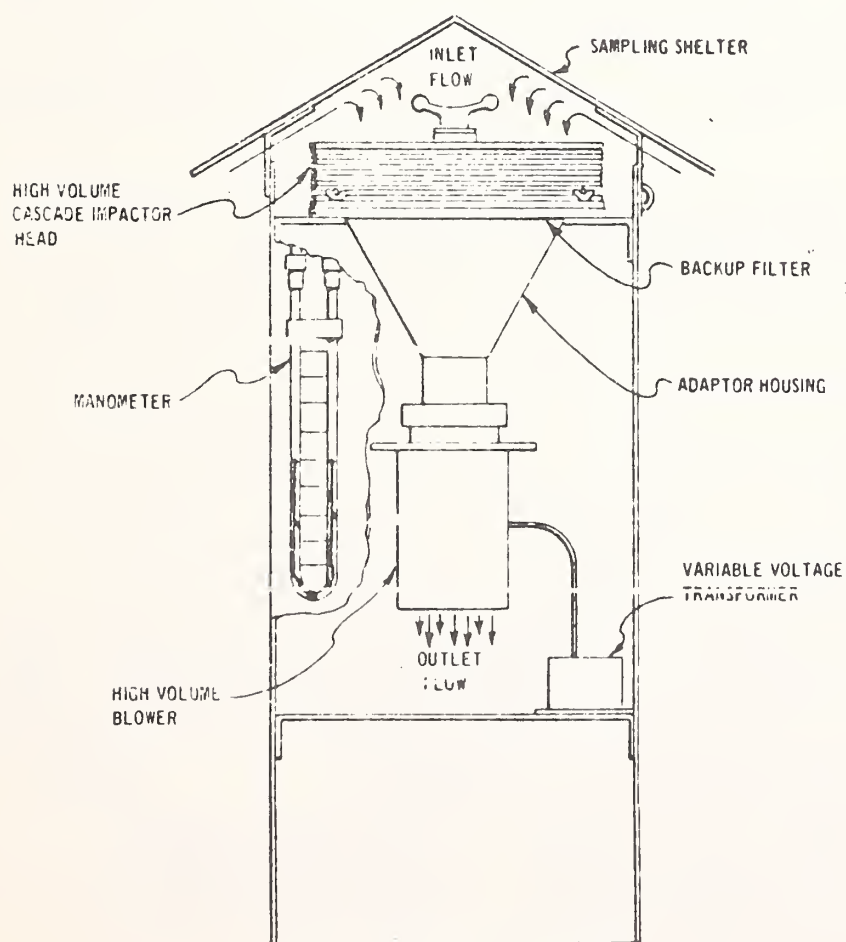


Figure 5 High-Volume Cascade Impactor  
With Backup Filter for Sampling Atmospheric Aerosols

air in a relatively short period of time. Disadvantages include substantial original costs followed by fairly high filter, operating and analysis costs. Electrical current also must be obtained, which limits sampler location.

2. Membrane Sampler. The membrane sampler collected total suspended particulate matter as did the hi-vol and impactor samplers. Since the air flow was approximately 3 to 4.5 cubic feet per minute the shelter inlet air flow through the shelter differed from that of the hi-vol and impactor in that the lower flow rate aerodynamically pulled in lighter particles. A large puller motor was needed to overcome the increased flow resistance of the cellulose membrane filter material which was 10 cm in diameter.

The sampler was used because the membrane filters do not in general contain the trace metal contamination associated with the fiberglass filters. The total membrane filter could be digested in acid during the sample preparation allowing for better chemical detection of trace elements than fiberglass filters. There are some flow problems associated with these filters since cellulose tends to pick up and retain moisture.

3. High-Volume Particle Fractionating Cascade Impactor. The high-volume particle fractionating cascade impactor, manufactured by Anderson 2000, Inc., is a multistage, multijet unit consisting of five aluminum jet plates separated by sized neoprene rubber gaskets (Figure 6). The plates are backed by a standard 8 by 10 inch hi-vol filter to collect submicron particles. Each plate is approximately 12 inches in diameter and contains approximately 300 sized jets. The alignment of the 12-inch plates and resulting air flow patterns direct the particle onto the surface of the jet plate below. The collection surface was covered with a cut and perforated fiberglass filter which had been preconditioned and weighed. The size and location of the jets are held to very close quality control tolerances to give proper fractionation. The collection medium contains punched holes so that it does not obstruct the jet openings in the plates. The head interface plate

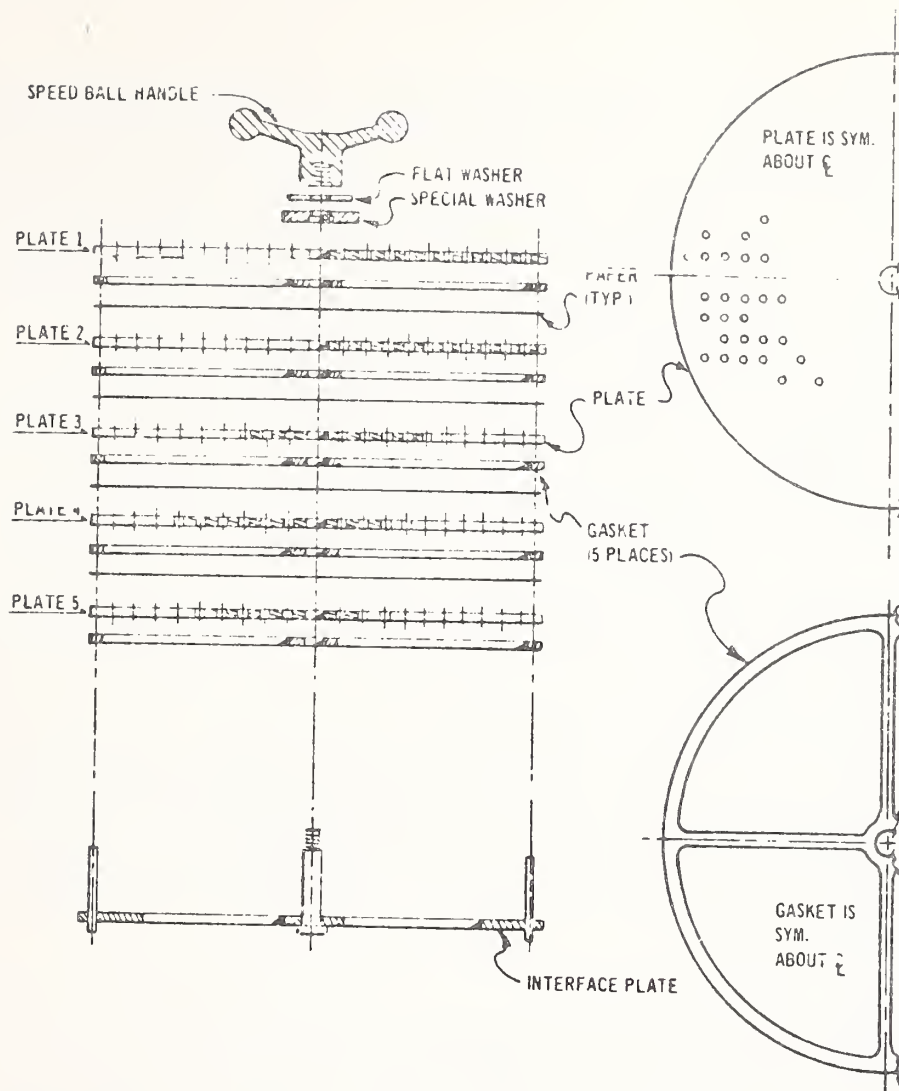


Figure 6 High-Volume Fractionating Sampling Head for Cascade Impactor

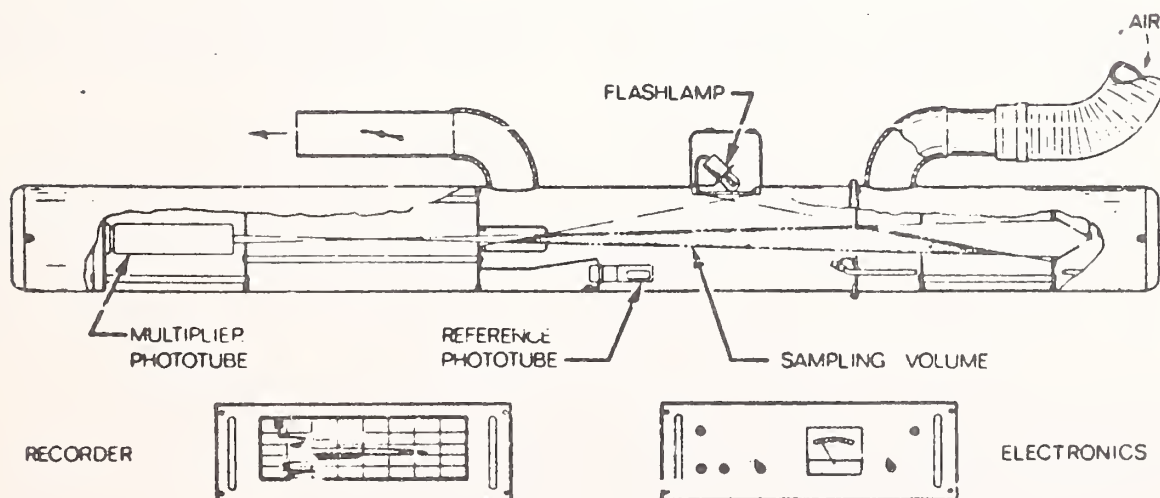


Figure 7 Mechanical Assemblies of an Integrating Nephelometer

contains four dowl pins and a center post for properly locating the jet plates with respect to each other and for aligning the collection medium with the jet plates. The assembled head is positioned on a 9 by 11 inch interface gasket and attached to a conventional hi-vol filter holder inside the hi-vol shelter (Figure 5). A standard hi-vol air mover was used for air flow through the system. The aerodynamic separation of the five plates allows the collections of: 7.0 microns(u) and above, 3.3-7.0 u, 2.0-3.3 u, 1.1-2.0 u and 0.1-1.1 u. Regulation of the air flow through the fractionator was achieved by adjusting a variable voltage transformer and noting the corresponding pressure drop through the assembled fractionator as indicated by a manometer. For proper fractionation and sizing, the fractionator should operate at 20 ft<sup>3</sup>/min. Since the fractionator collects the major portion of samples, and especially the large particles, the flow rate will remain constant except for minor line voltage fluctuations.

4. The Dustfall Jar. Basically the dustfall jar may be any of a variety of open top cylindrical containers into which the larger and more dense fraction of atmospheric pollutants may settle. The DHES in general used standardized plastic containers with screw-on lids for transporting to the laboratory. A fairly large jar with restricted mouth was used to prevent particles from becoming re-entrained into the ambient air by wind. To facilitate retention of particles deposited therein, water with either an algicide for summer usage or anti-freeze in winter months was used.

The sampling procedure used was to place an open-mouth container high on a pole and away from buildings or other structures which would interfere with fallout of particulate from the atmosphere. The container was then left for one month, after which the sample was returned to the laboratory. The amount of settleable particulate was then determined gravimetrically on an analytical balance. The sample could also be used to determine individual chemical constituents if desired. The grams of particulate per area exposed was then converted to tons/mi<sup>2</sup>/mo. Local conditions such

dusty roads could cause results to vary widely. Interferences such as leaves, twigs and bird droppings could affect results but were partially removed by screening the sample before weighing.

Replicate samples by various investigators indicated a precision of  $\pm 15\%$  is attainable for any given combination of collecting element and retention fluid. Results of greater than 2 to 1 variation have been found with replicate samples taken by different methods. Thus the method is not precise. It is, however, simple and inexpensive and gives an indication of the amount of settleable particulate in a given area.

5. Bendix Infrared Gas Analyzer. A Bendix Model 8501-5B infrared gas analyzer was used to monitor carbon monoxide (CO) levels in the ambient air. The infrared gas analyzer utilized the nondispersive single beam technique, with alternate modulation of the sample and reference cells. The principal of measurement used was based on CO having a known characteristic absorption spectra in the infrared range. The reference cell was filled with a nonabsorbing gas and sealed, and the sample was passed through the sample cell. With no CO present in the sample, the amounts of radiation coupled into the detection chamber from the sample and reference cells was essentially equal, effectively cancelling and producing no output. When CO was present in the sample, it absorbed some radiation, causing inputs to be unequal, and producing an output from the detection chamber. The detection chamber used was designated so that the output was proportional to the concentration of CO. The output was transcribed as a trace on a strip chart. The ambient sample was passed through particle filters before it entered the detection cell. This insured clean samples and the absorption process was not contaminated by dust.

6. Bendix Ozone, NO and NO<sub>x</sub> Monitors. Ambient air concentrations of ozone and oxides of nitrogen (NO<sub>x</sub>) were monitored by Bendix Corporation instruments which utilized the principal of photometric detection of chemiluminescence resulting from flameless reactions between the substance being monitored and a co-reactant.



Chemiluminescence was the production of light waves or photons as a result of flameless phase reactions between the substances. These photons were transmitted to a photomultiplier tube in numbers proportional to the amount of CO, NO<sub>x</sub> or ozone drawn into the process from the ambient air. The tube converted the light energy of the photons into electrical energy which was further amplified by the electrometer amplifier to provide proper drive voltages for the panel meter and strip chart recorder. Thus, the resulting readings were proportional to the light produced by the flameless reaction, which in turn was proportional to the ambient concentration of ozone, NO or NO<sub>x</sub>, whichever was being measured.

The ozone monitor utilized the flameless phase reaction between ozone and ethylene, while the NO, NO<sub>x</sub> monitor utilized the reaction between NO and ozone. In both monitors the ambient air was passed through particulate filters then into the reaction chamber where it was combined with its co-reactant.

7. Philips PW 9700 SO<sub>2</sub> Monitors. Ambient air sulfur dioxide (SO<sub>2</sub>) concentrations were converted to electrical signals by a Philips PW 9700 SO<sub>2</sub> monitor. These electrical signals were then displayed on a strip chart recorder. Before entering the detector cell, the air to be monitored for SO<sub>2</sub> had to be free of dust, ozone, hydrogen sulfide and other materials that might interfere. Dust was removed by a fiber filter in the sampling head, the other substances were removed by a silver filter inside the chemical unit. The cleaned air was then passed through an aqueous solution of KBr, Br<sub>2</sub> and H<sub>2</sub>SO<sub>4</sub>, at the rate of about 150 ml/min. SO<sub>2</sub> in the air reacted with the solution to ionize the bromine, resulting in current flow between two electrodes. The current flow reunited the ions into free bromine. The amount of current needed for this reaction was directly proportional to the quantity of bromine ionized, which in turn was directly proportional to the quantity of SO<sub>2</sub> which flowed through the cell and reacted with the bromine. The amount of SO<sub>2</sub> in the ambient air thus was recorded in terms of the amount of current drawn by the process. Air flow was kept constant with the aid of a critical orifice and a vacuum pump.



8. Bubble Sampling ( $\text{NO}_2$  and  $\text{SO}_2$ ). Atmospheric nitrogen dioxide ( $\text{NO}_2$ ) and sulfur dioxide ( $\text{SO}_2$ ) concentrations were monitored both by continuous analyzers and bubbler methods. The sampling procedure for both pollutants was the same except for the absorbing solution. Ambient air was drawn into a polypropylene tube and bubbled through the absorbing solution. The air flow was maintained around 200 ml/min by a critical orifice. Both the orifice and the pump that maintained pressure on the orifice were protected by a moisture trap and a particulate filter. Pressure on the orifice was checked before and after a sample was taken. The critical flow through the orifice was checked between samples. After collection the samples were refrigerated until they were mailed to Helena for chemical analysis.

Nitrogen dioxide was collected by bubbling ambient air through a solution of sodium hydroxide and sodium arsenite. The nitrite ion produced during sampling was determined colormetrically by reacting the exposed absorbing reagent with sulfanilamide and N-1 naphthylethylene diamine dihydrochloride. The sample was run 72 hours. Fifty mls of absorbent solution allowed detection of 5 to 750 ug of  $\text{NO}_2$  per cubic meter of air for a 72 hour, at 200 ml per minute.

Sulfur dioxide was absorbed from ambient air in a solution of potassium tetrachloromercurate (TCM). The dichlorosulfite-mercurate complex was stable to strong oxidants. The complex was reacted with pararosaniline and formaldehyde to form intensely colored pararosaniline methyl sulfonic acid. The absorbence of the solution was measured spectrophotometrically. Fifty mls of TCM allowed a range of 25 to 1050 ug of  $\text{SO}_2$  per cubic meter of air over a 24-hour period at 200 ml/min flow. All bubble samples were 72-hour samples (3 days).

9. Integrating Nephelometer. The integrating nephelometer used was manufactured by Meteorology Research, Incorporated and was comprised of two major assemblies. The first was the sensor unit consisting of the optical assembly with its calibrator, flashtube and two phototubes together with its associated air sampling equipment including ducts, filters and pumps. The second part was the electronic control

module containing the necessary amplifiers, power supplies and an indicating meter for monitoring the output from the instrument.

The mechanical assembly was made in a four-inch diameter aluminum tube approximately 44 inches long. The general layout is shown in Figure 7. The flash lamp behind its opal glass screen was mounted on one side of the tube. The multiplier phototube was located in one end of the tube and detected the scattered light from the illuminated air sample. The light trap and calibration mechanism were situated in the other end.

The reference phototube was mounted in the chamber containing the air volume to be measured. The air to be sampled was drawn into the sampling chamber through an intake duct with the air movement provided by a vacuum blower mounted in the outlet ducting, moving approximately 10 cubic feet of air per minute. This flow rate was not critical and did not affect the visibility readings.

The nephelometer had three scales, indicating the light scattering coefficient, the meteorological range, and the mass concentration.

The meteorological range ( $L_v$ ) scale was based on the Koschmieder visibility theory stating that:

$$L_v \approx \frac{3.9}{b_{550}}$$

The relationship between the scattering coefficient at 550 nm,  $b_{550}$  and that at 500 nm,  $b_{500}$  was:

$b_{550} \approx 0.84 \ b_{500} \approx 0.84 \ b_{\text{scat}}$  where  $b_{\text{scat}} = b_{500}$  was the quantity indicated by the instrument so that:

$$L_v (m) \approx \frac{4.7}{b_{500}} = \frac{4.7}{b_{\text{scat}}}$$

The meteorological range scale was based on a large number of experiments relating light scattering, mass concentration and visual range as well as the correction factors discussed above. The best current value for the relationship of meteorological range and mass concentration is:

$$L_v \times \text{mass} = 1.8 \text{ g/m}^2$$

In order for the units of this expression to come out correctly,  $L_v$  was put into meters and mass concentration into grams per cubic meter. This quantity represents the mass of material in a box one meter in cross section and of length  $L_v$ . This can be restated in more convenient units where mass represents mass concentration:

$$\text{Mass} = \frac{1.8 \times 10^3}{L_v \text{ (km)}} \quad (\text{ug/m}^3)$$

Alternatively, the relationship between light scattering coefficient,  $b_{\text{scat}}$  as indicated by the primary scale and mass concentration is:

$$\text{Mass (ug/m}^3\text{)} = 3.8 \times 10^{5b_{\text{scat}}} \text{ (m}^{-1}\text{)}$$

It is important to state very clearly that the nephelometer measured only light scattering and not mass concentration or visual range. However, the published relationships between these two quantities and scattering are certainly useful and are therefore given as secondary scales.

The absolute accuracy of the integrating nephelometer was somewhat difficult to estimate since there was no other instrument for comparison. Studies of the correlation of nephelometer output with visual range as well as theoretical considerations suggest that the calibration was correct to within  $\pm 10\%$ . However, the relative accuracy was perhaps more important since it governed the reproducibility of the measurements. Absolute accuracy could not affect reproducibility since it was controlled by systematic errors. The relative accuracy was governed by the signal-to-noise ratio which was typically about 20-50 for scattering by city air. Thus, the overall relative accuracy should have been about  $\pm 2$  to 5%.

10. Sulfation Plates. The sulfation plate for determining  $\text{SO}_2$  concentrations was made by attaching a 4.8 centimeter diameter Gelman A fiberglass filter to a 4.8 centimeter diameter petri dish with three drops of acetone. The lead dioxide solution to coat the petri dish was made in the following manner. 112 grams of lead dioxide was blended in a blender with 700 milliliters of water, 0.7 grams of gum tragacanth, and 7 grams of fiberglass filter ground on a Wiley mill to pass 20 mesh. Ten milliliters of this material was transferred into each petri dish.

The coated dish was dried in an oven at low temperature (60°C) and sealed with a lid.

To expose a sulfation plate, the lid was removed and the plate was placed in a bracket that secured the sulfation plate upside-down (Figure 9). The petri dish served as the shelter, shipping container, and lead dioxide support. The sulfation plate was exposed for approximately 30 days.

After exposure, the lead dioxide was removed from the petri dish with a little water. The insoluble lead sulfate was converted to soluble sodium sulfate with the aid of 20 ml of sodium carbonate solution (50 grams/liter) and heat. The excess insoluble lead dioxide was removed by filtration. The solution was acidified with hydrochloric acid to bring the pH of the filtrate between 2 and 3. The acidified filtrate was diluted to 50 ml or any other convenient volume with water. A portion of this solution (up to 25 ml) was then diluted with 25 ml of water. To this, 0.1 gram of sulfur powder was added, mixed and let stand 20 minutes. The resulting turbidity was measured in a spectrophotometer at 450 millimicrons.

11. Sodium Formate Plates. This sampling technique was used to measure monthly levels of fluoride in the air. The fluoride collection media used was a Whatman 41 filter paper (4.7 cm diameter) attached to a petri dish with three drops of acetone. The filter discs were immersed in a 50% ethyl alcohol solution containing 10% sodium formate. These discs were air dried at room temperature in a fluoride free area.

To expose the fluoride plate, the lid was removed and the plate was placed in a bracket that secured the fluoride plate upside-down (Figure 9). The petri dish served as the shelter, shipping container and fluoride plate support. The fluoride plate was exposed for approximately 30 days.

The exposed filter paper was removed from the petri dish and placed in a 100 ml polyethylene beaker. The filter paper was covered with 20 ml of distilled water and let stand for 2 hours. Next 20 ml TISAB buffer solution was added and the fluoride concentration was read on the fluoride electrode as the solution was stirred with a



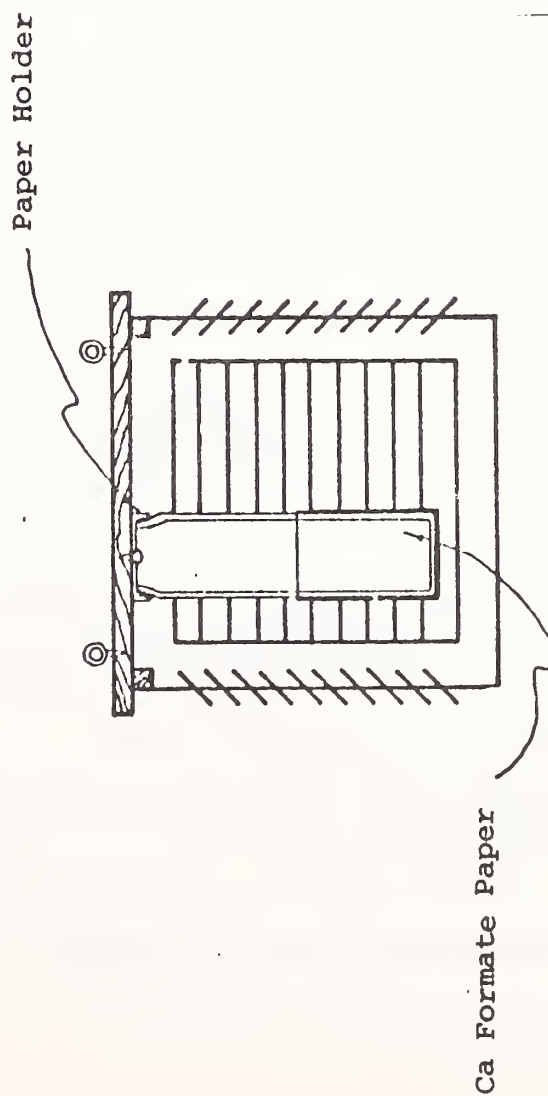
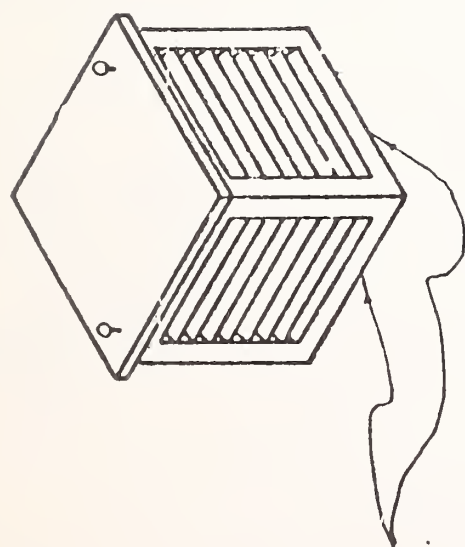
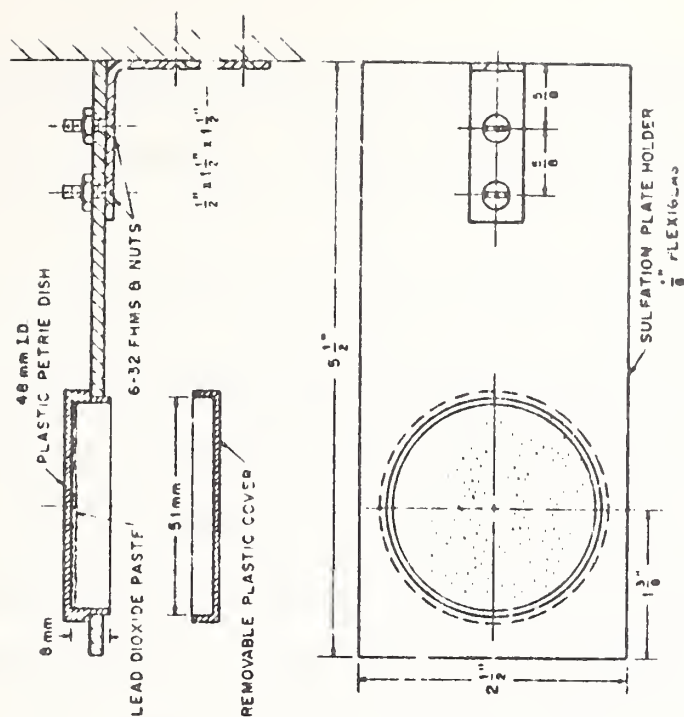


Figure 8 Montana Box For Holding Ca Formate Papers for Sampling Fluorides in the Air



**Figure 9** Holder for both Sulfation Plate and Na Formate Plate Samplers.

The range of measurement of the fluoride electrode was 0.019 to 19,000 ppm soluble fluoride. However, the recommended range of analysis for air samples was between 0.1 and 10 ppm.

12. Calcium Formate Papers. Ambient air samples for fluoride were also collected with the use of filter paper impregnated with calcium formate. The 11 centimeter filter papers were prepared by soaking Whatman No. 2 papers in a solution of 10% calcium formate (10 grams calcium formate dissolved in 100 ml distilled water) for approximately 5 minutes and drying them in a forced air oven set at approximately 80 C for about one hour or letting them dry overnight in a room free of fluoride.

The filter papers impregnated with calcium formate solution were exposed in a standard louvered shelter (Montana box) for approximately 30 days (Figure 8). The shelters gave protection from normal rainfall and snow, while permitting free flow of air over the papers. They were installed about 2 meters above the ground, clear of shielding objects.

After the papers had been exposed for approximately 30 days, they were fired in inconel crucibles in a muffle furnace for approximately one hour at 600 C. The ashed papers were dissolved with 100 ml of 1-1 HClO<sub>4</sub> and diluted to 250 ml with distilled water. Using the auto-analyzer, the solution and sulfuric acid were pumped into the Teflon coil of a microdistillation device maintained at 170 C. A stream of air carried the acidified sample swiftly through a coil of teflon tubing to a fractionation column. The fluoride and water vapor distilled from the sample were swept up the fractionation column into a condenser and the condensate passed into a small collector. The distillate was pumped continuously from the sample collector. Acid and solids were removed from the bottom of the fractionation column and drawn to waste. The distillate was mixed continuously with alizarin fluorine blue-lanthanum reagent, and the colored stream passed through a 15 mm tubular flow cell of a colorimeter, where transmittance was measured at 620 mu. The impulse was transmitted to a recorder.



This method could detect values as low as 0.1 ug F/ml. The operating range of the recorder was 0.1-2.0 ug F/ml. Higher concentrations had to be diluted with a 1 to 1 solution of HClO<sub>4</sub>.

## B. Vegetation

The Air Quality Bureau vegetation study was restricted to the Riparian communities along rivers, creeks, and coulees in the Colstrip vicinity. Twenty-four sampling sites were chosen in the vicinity of Colstrip along imaginary radii placed at the 8 cardinal points. Three sites were chosen along each radius at approximately 5, 10, 15 miles from the power plant. Besides these plots, permanent control plots were established south of Birney P.O. along the Tongue River, and south of the Custer Battlefield along the Little Bighorn. Twenty ecological study sites were established along the Tongue River east and southeast of Colstrip. Here baseline data on the Riparian plant community was computed in addition to vegetation sampling. Parameters measured included relative frequency, density, and dominance of plant species besides estimated height and age of overstory and understory trees. This habitat type was chosen for two basic reasons: (a) Its choice would complement studies of other agencies and individuals involved in the project without replicating efforts; (b) Its constituent members consist of trees which are known to be sensitive species are: Willow, Boxelder, Snowberry, Milkweed, Bluegrass and Rose. The fluoride sensitive species of these communities include: Boxelder, Green ash, Chokecherry, Yellow clover and Lambsquarters.

At each sampling site, a tree, fencepost or telephone pole was labeled with a permanent site identification tag including the bureau initials, the approximate direction from Colstrip, and the interval number of the site. For example: AQB SE1 would indicate the Air Quality Bureau sampling site No. 1 on the southeast directional transect, approximately 5 miles from Colstrip.

Vegetation samples were collected at all 44 sites. The species included: Boxelder, Hawthorn, Green ash, Cottonwood, Chokecherry, Golden currant, Prairie rose,

Snowberry and Willow. It is important to note that this complete set of species was not present at each of the 44 sites. Methods for collecting the samples at the sites were as follows: Each sample was compound, a portion being collected from all plants of each species growing within a 15 x 6.7 m plot at each sampling site. The samples were taken from the four cardinal points around the plant or tree. For uniformity the samples were taken from breast height or eighteen inches from the ground, depending on the plant. With high overstory trees the sample was taken with the aid of a 30 ft. extendible pruner. Samples collected included only leaf tissue, the stems having been removed. Each compound species sampled was placed in a paper bag and labeled with the site identification number and date. The frequency of the species chosen for sampling was great enough to insure adequate replication.

With the 20 sites along the Tongue River (TR-1 through 20) a baseline data inventory was made including species frequency, dominance, density, age and height, in addition to chemical analyses of plant tissue. The method used was that of Lewis F. Ohmann (6). This method is useful in identifying qualitative and quantitative information regarding temperate forest natural areas. The method is also valuable in describing uniform plant communities such as those occurring along a river. The Riparian communities along the Tongue River in southeastern Montana lent themselves to this method because of their natural state, homogeneity, and uniform history. Sampling plots were randomly chosen within sections of land on which the state Air Quality Bureau had received permission to conduct sampling. All plots were located on either Hunt Oil Co. or state land. Twenty nested quadrant sampling plots were chosen within these areas. The Ohmann method considers this quantity adequate for statistical purposes (6).

On each data sheet the plot compass bearing and sufficient state locale descriptions were noted. A tree, fence post or telephone pole proximate to the lower left corner of the plot was permanently labeled with the site identification number. These site ID labels were made of black plastic with a red background and were mounted

permanently. The sampling plots were rectangular with overall dimensions of 15 x 6.7 meters (Figure 10). All overstory trees and saplings of over 2.54 cm (1 inch) diameter at breast height (dbh) were included in this large plot. Seedlings and shrubs with diameters under 2.54 cm dbh were included in the 4 x 1 meter nested plot. Finally low shrubs, forbs and grasses were included in the 2 by 0.5 meter nested plot (Figure 10).

Within each nested plot the frequency of each species present was recorded. With trees and saplings the dbh was recorded using a Lufkin tree tape. Heights of overstory and understory trees were recorded using a Luunto clinometer. Trunk borings were taken using a Jim Gem stainless steel borer. Data collected from each plot was recorded on separate data sheets in the field.

In the 1 x 4 m nested plots the seedlings and tall shrubs were recorded according to species, frequency and diameter class. Diameter class 01 was used for plants having a diameter between 0.1 to 1.0 cm and class 02 was used for those having a diameter between 1.0 and 2.0 cm. These diameters were measured at approximately 18 inches from the ground.

In the smallest plot (Figure 10) low shrubs and forbs were included. This plot was used to record the name and projected ground cover for each species, covering more than 1 percent of the plot area. Also an estimation of bare ground and litter was made.

The basic data collected from the nested plots included the number of plots on which each species occurred, the number of total stems counted per species per plot, and the total basal area these stems occupied. From these values all other information is derived.

The percent frequency was computed as the percent of the plots in which the species occurred.

The average density was computed as the average number of stems per plot per species expressed per acre. Since the large plots in this study were 1/40 acre in

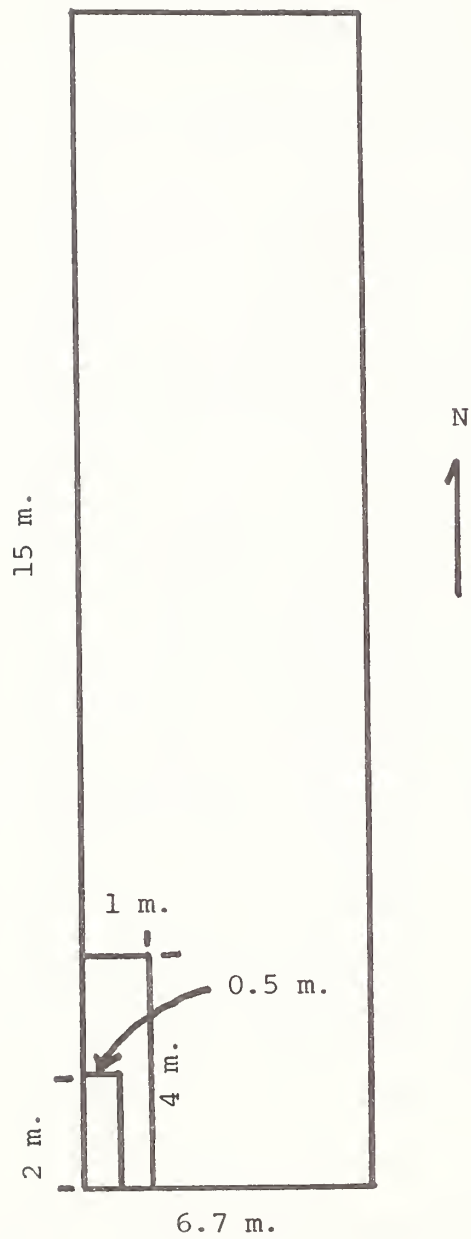


Figure 10 - Nest of rectangular plots with permanent marker at one corner of all three plots. Long axis of this nest is north-south for ease in relocation.

area the number of stems of Ash were, for example, multiplied by a factor of 40. In the same manner the stem data for the 4 x 1 m plot was multiplied by a factor of 1000 while that of the 2 x 0.5 m plot was multiplied by a factor of 4000.

To determine plant species dominance the stem diameters were converted to their area equivalent using the formula  $A = \frac{\pi(\text{dbh})^2}{4}$ . Once this was determined for each species/plot it was expanded for an acre size area.

Once the values for density, frequency and dominance were determined, the relative values were computed.

For the tree and sapling data from the large plot values were computed as follows:

#### I. Species relative frequency (RF):

$$\text{Species RF} = \frac{\% \text{frequency of each species}}{\% \text{frequency of all species}} \times 100\%$$

This value indicates the percent total frequency which is contributed by each species (6). For example, with Chokecherry Prunus virginiana, the plot frequency was 55/225 or 24.4 in terms of relative frequency.

$$\text{Chokecherry RF} = \frac{55}{225} \times 100\% = 24.4\%$$

#### II. Species relative density (RD):

The species relative density value represents the percent of total stems which is contributed by each species. This quantity was computed in this fashion:

$$\text{Species RD} = \frac{\text{Number of stems counted for each species}}{\text{Number of stems counted for all species}} \times 100\%$$

For example, with Chokecherry the mean number of stems/acre was 136.59 thus:

$$\text{Chokecherry RD} = \frac{136.59}{604.19} \times 100\% = 22.7\%$$

III. Species relative dominance was derived from the basal area data which was in the form of ft<sup>2</sup>/acre. Relative dominance was computed as follows:

$$\text{Species R Dom: } \frac{\text{basal area of each species}}{\text{basal area of all species}} \times 100\%$$

Again with the example of Chokecherry the basal area/acre was 2.70 square feet. Thus the species R Dom:



$$\text{Chokecherry R Dom} = \frac{2.70}{174.38} \times 100\% = 1.50\%$$

IV. The importance value for each species was computed by taking the mean of the three above values. Thus the formula used was:

$$\text{Species Importance Value} = \frac{\text{RD} + \text{RF} + \text{R Dom}}{3}$$

With the example for Chokecherry was computed as:

$$\frac{22.7 + 8.9 + 1.5}{3} \times 100\% = 11.03\%$$

This value ranked the tree species in terms of their relative importance within the community.

For the 1 x 4 m plot, the data collected contained information concerning shrubs and saplings. Calculations computed on these data are identical with that of the larger plots. Since, however, the plot size is 1/1000 of an acre, the factor for determining the mean number of stems/acre was 1000. Also within this size plot the constituents had dbh determined in terms of increment classes with 01 = 0.1 - 1.0 cm and 02 = 1.0 - 2.0 cm. In calculating the basal area the midpoint of each class was used. Thus stems included in class 01 had a dbh of 0.5 cm for the purpose of determining mean basal area while those of class 02 had 1.5 cm.

Once the total number of stems/acre and total basal area/acre were determined, the relative values for density, dominance, frequency and importance were computed. Here the formulas used were identical with those of the tree and sapling size class.

For low shrubs, forbs, and grasses there was an estimation of percent plot covered by projection of foilage onto the ground. This percent cover was used for frequency computation. Dominance was computed as the average percent cover. This was computed as the total estimated cover averaged over the number of plots. Relative frequency and relative dominance were computed with the tree strata. Also here an estimation of bare ground and litter was included.

At each plot along the Tongue River estimates were made of tree heights. Here overstory, understory and sapling heights were determined on constituent species.



Borings were taken of representative overstory and understory trees in order to determine age.

In the laboratory analysis procedures, the vegetation samples selected for analyses were placed in acid washed beakers, labeled as to site and species, and dried at 80°F for 24 hours using a heat lamp. Following drying, each sample was ground in a Wiley mill with a 40 mesh screen and placed in a plastic sample bag. Enough samples was prepared to furnish tissue for fluoride and eventual sulfur and heavy metal analyses.

The fluoride analyses involved the use of a Technicon auto-analyzer. The method used was based on the distillation of hydrogen fluoride and subsequent reaction of this distillate with the reagent alizarin fluorine blue lanthanum. The reaction forms a lilac blue complex which was measured colorimetrically at 620 nm. The detection limit of this method was 0.06 ug/ml. The process used was as follows: A 1.0 gm sample was weighed out and placed in an inconel crucible. To this was added 100 mg of calcium oxide, sufficient distilled water to make a slurry and 2 drops of phenolphthalein. This was mixed thoroughly with a polyethylene policeman to yield a red mixture. The mixture was evaporated to dryness under infrared lamps. Then the samples were charred on a hot plate for one hour. The crucibles containing the charred samples were placed in a muffle furnace at 600°C and ashed for 2 hours. After ashing, 3 g of sodium hydroxide pellets was added to each crucible. The crucibles were then placed in the furnace for 3 minutes with the door closed. Next each crucible was removed and swirled to suspend all particulate matter until the melt was partially solidified. The crucible was cooled and then washed down with 10-15 ml of distilled water on the inner walls. After crucibles cooled to room temperature the melt was transferred to a plastic tube graduated at 50.0 ml with distilled water. The crucible was rinsed with 50% V/V perchloric acid solution and the rinse was added to the tube. The sample was diluted to a final volume of 50.0 ml with distilled water.

The sample fluoride content in ug/ml is:

$$F_t = \frac{F_s V_s D}{W_s}$$

Where:  $F_t$  = ug/ml of fluoride in the sample

$F_s$  = ug of fluoride/ml of unknown sample as taken from the calibration curve

$V_s$  = volume in ml of the unknown sample (usually 50 ml)

$D$  = dilution factor used when fluoride in unknown sample exceeds the standard curve

$W_s$  = weight of sample taken for analysis in grams

A continuous flow of cooling water entered the instrument condensers. The vacuum gauge was adjusted to read 8 psi. The suspended digest and sulfuric acid were pumped into a teflon coil of a microdistillation device at 170°C. A stream of air carried the acidified sample through the teflon coil to a fractionation column. The fluoride and water vapor distilled from the sample were swept up the fractionation column into a condenser. The condensate passed into a small collector. The distillate was pumped continuously from the sample collector. Acid and solids were removed from the bottom of the fractionation column and drawn to waste. The distillate was mixed continuously with alizarin fluorine blue lanthanum reagent, the colored stream passed through a 15 mm tubular flow cell of a colorimeter, and the absorbance was measured at 624 mμ. The impulse was transmitted to a recorder.

The absorbance of the alizarin fluoride blue lanthanum solution is changed by very small amounts of inorganic fluoride. This system minimizes interference of metal cations and inorganic phosphate since they are not distilled in this system. Also the organic substances which might interfere are destroyed during the preliminary ashing.

### C. Soils

The soil samples were collected in May, 1974 using standard procedures recommended by soil scientists at Montana State University. A soil sampling corer from Elano Corporation of Xenia, Ohio, was used to extract the soil cores. At each site 8

cores were extracted at random within a 2 x 6 M plot. Each core was separated into an A<sub>1</sub> and B<sub>2</sub> horizon. Corresponding horizons from these 8 cores were mixed and a sample for analysis was taken. Thus a compound A<sub>1</sub> horizon and B<sub>2</sub> horizon sample was extracted from each sampling plot. Note that the size of the 8 constituent cores forming the final sample varied somewhat within each sampling plot due to slight differences in horizon thickness. The intraplot variation between horizons was somewhat less than in interplot variations. The A<sub>1</sub> and B<sub>2</sub> horizon samples were placed in plastic sample bags and labeled.

The pH of the soil samples was determined using an electrode pH meter. Twenty ml of deionized water was added to each 10 gm field sample. The pH was determined by lowering the electrode into a beaker containing the soil water mixture. This was a standard method which was recommended by state soil scientists. Its sensitivity was within a range of 0.1 pH.

Following the pH determinations, 0.1 gram of dry soil was placed in a nalgene beaker. To this soil sample were added 5 ml of 12N HCl and 5 ml of 12N HF. The sample was heated on a boiling water bath just to dryness. This process was repeated with 3 ml HCl and 3 ml HF being added to the dry sample. Then 5 ml of 12N HCl was added and the sample was taken just to dryness. This was followed by adding 2 ml of HCl and heating on a water bath. A stirring rod was used to break up any particulate matter. The stirring rod was rinsed into the beaker with deionized water until the total volume in the beaker was between 10 and 15 ml. The beaker containing the soil sample was heated until the soil was dissolved. The sample was brought up to 50 ml with deionized water. It was then poured into a labeled sample bottle.

Once in aqueous form the sample was ready for chemical analyses of individual elements by a Varian Techtron Atomic Absorption Spectrophotometer (AA). This instrument contained the following components: a burner apparatus which produces an atomic vapor of the sample being analyzed, a lamp component for the hollow cathode lamp, a monochromator, a photomultiplier tube and an electronic assembly for providing a readout for information.

Light was passed from the hollow cathode lamp to the monochromator via a system of lenses on opposite sides of the burner compartment and an adjustable mirror mounted in the gas control compartment. A light chopper assembly which synchronized the electronics system was automatically activated when the emission mode was selected. The operator selected modes of operation and controlled the functions from the control panel. This involved selection of flame emission, percent transmission, concentration mode, and absorbance mode.

A support gas entered the nebulizer drawing the sample solution through a capillary tube and breaking it into a fine spray. The fine spray sample was mixed with a fuel gas. The sample and fuel gas were ignited in the burner. When burned, each element gave off light of a particulate nature, within a narrow frequency band. This narrow band was detected by the monochromator and passed through a photomultiplier tube where it was amplified. An electrical impulse from the photomultiplier tube was recorded on a recorder or meter. The final electrical impulse recorded was proportional to the concentration of the element in the sample.

The following elements were analyzed using flame Atomic Absorption: Na, K, Ca, Mg, Li, Sr, Cu, Zn, Fe, Cr, Mn. Note that with Ca, Mg and Sr, 10,000 ug/ml of lanthanum oxide was added to each sample. With K, 1000 ug/ml of Cs<sup>+</sup> was added to the sample. With Na and Li, 2000 ug/ml of K<sup>+</sup> was added to the sample.

The method of analyzing As used was that of the Association of Analytical Chemists. A magnesium oxide-magnesium nitrate slurry was made by suspending 75 gm of MgO and 105 gm Mg(NO<sub>3</sub>)<sub>2</sub> in enough water to make one liter. Two and one-half grams of the dry sample were placed into a 70 ml ashing dish. Fifteen ml of the slurry and sufficient water were added to wet the sample. The sample was mixed with a glass stirring rod and dried at 100°, then ashed in a muffle furnace at 550° for 2.5 hours. The ash was cooled and moistened with water and 15 ml of 6NHCl. The mixture was allowed to stand overnight. The dissolved ash was then filtered into a 125 ml erylenmeyer flask. The residue was washed until 60 ml was collected. Ten ml of 6NHCl, 2 ml 15% KI solution, and 0.5 ml of SnCl<sub>2</sub> were added to the filtrate. The solution was



swirled and let stand 20 minutes. Three ml of Ag diethyl-dithiocarbamate solution was placed in the sample receiver. Five grams of zinc was added to the sample and arsine was generated and collected in the sample receiver for 45 minutes.

The method for Se analysis involved special adaptation of flame atomic absorption. The procedure used was as follows: in the reaction vessel was placed twenty ml of solution containing between 50 and 500 ml of selenium, acidified with 40% HCl and 10% H<sub>2</sub>SO<sub>4</sub>. One ml KI solution and one ml Sn Cl<sub>2</sub> solution were added to the reaction vessel. Two ml of a zinc slurry or zinc powder 1g/ml distilled H<sub>2</sub>O was syringed into the reaction vessel solution. A vigorous reaction occurred and a peak was recorded as the sample was purged to the flame of the atomic absorption spectrophotometer.

Following preliminary hydrolysis, ashing and dissolving the following elements were analyzed using a carbon rod atomizer: Sn, Sb, V, Ag, Be, Pb, Cd, Hg. This technique insured increased efficiency and sensitivity in determining trace element amounts. The carbon rod atomizer was essentially a miniature furnace chamber. It caused a small discrete volume of sample solution to be totally vaporized, eliminating wastage. Optimum absorbance conditions were rapidly attained by this procedure for a specific amount of analyte. The process used involved three steps.

- (1) evaporation of the solvent
- (2) ashing and decomposition of the chemical compounds in the dried sample and vaporization of matrix components.
- (3) vaporization of the analyte with the production of free atoms.

As with flame atomic absorption, free atoms were produced altering the light seen by the monochromator. This characteristic light was amplified in a photomultiplier tube, transformed into an electrical signal and recorded in an analyte absorbance peak proportional to the concentration of the sample.

In the case of Hg analysis, the determination was carried out with flameless atomic absorption. The procedure was as follows: the aqueous sample containing the Hg was dissolved using a 1/3 HNO<sub>3</sub>, H<sub>2</sub>SO<sub>4</sub> solution. Following dissolving it was

heated on a boiling water bath for 3 hours. Next the sample was brought up to 25 ml with distilled water. One ml of the sample was put into the special apparatus for Hg analysis. One ml of a 20%  $\text{SnCl}_2$  solution was added to the apparatus. The Hg vapor was pulled into a carbon gold lined cup. The Hg collects on the gold lining. The carbon cup with the collected Hg was placed into the carbon rod atomizer furnace of the AA where vaporization occurred and free atoms were produced, again giving rise to a characteristic light frequency which revealed the amount of Hg in the sample.

The atomic absorption spectrophotometer used in these analyses was a Varian Techtron Model 1200 for flame atomic absorption. The Varian Techtron Model 69 carbon rod atomizer was used for flameless atomic absorption. The concentration of the sample is transferred into absorbance units. Peaks with absorbance down to 0.001 can be measured. In the concentration mode peak signals down to 0.005 absorbance can be measured. The peak heights are relative measurements and cannot be taken as absolute absorbance values. Standard solutions ranging in concentration are used to prepare a standard curve from the feedout data. The range of these standards is adjusted to include the levels expected to be found in the samples.

Routine maintenance of the AA included cleaning and wiping with a soft cloth moistened with ethyl alcohol. Occasionally, the burner assembly was removed and scrubbed. The nebulizer was cleaned daily by nebulizing a 50 ml aliquot of distilled water through the spray chamber system at the end of each operating shift.



APPENDIX B  
DATA TABULATIONS



TABLE 11  
TOTAL SUSPENDED PARTICULATE DATA  
MILES CITY AOCR  
Jan. 1972 - Dec. 1972

Station	Minimum	Frequency Distribution (% of values equal to or less than stated one)								Maximum	Arith. Mean	Math. Std. Dev.	Geo. Mean	Geo. Std. Dev.	Total No. Obs.	Number of Samples Reported Per Month											
		10%	30%	50%	70%	90%	95%	98%	Jan.							Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	
Asay's Res. Custer Co. 1040001	8	14	28	54	104	237	288	394	405	90	93	55	3	111	8	10	10	9	10	10	9	3	10	11	11	10	
LaFlamme Powder River 1240006	8	18	25	36	51	82	105	105	150	47	32	30	2	26	0	0	0	1	3	4	0	3	5	4	4	2	59
Kluver Ranch Rosebud Co. 1360009	3	6	10	14	23	52	53	87	111	24	24	17	2	36	0	0	0	5	5	4	5	4	1	3	4	5	
Ira Grescis Rosebud Co. 1360021	7	13	44	67	114	190	191	257	284	92	71	63	3	35	0	0	0	4	5	4	5	5	5	1	2	4	
Bailey Ranch Rosebud Co. 1360024	2	2	4	5	8	10	10	10	10	6	3	6	1	10	0	0	0	0	0	0	0	0	0	1	4	5	
Hardin MDU Big Horn Co 0680001	24	28	44	59	63	116	135	145	147	67	34	59	1	37	0	0	0	3	4	5	4	4	4	4	5	4	
Carlott Ranch Big Horn Co. 0060008	3	3	4	8	10	25	25	25	25	9	7	8	2	7	0	0	0	0	0	0	0	0	0	1	3	3	

TABLE 12

TOTAL SUSPENDED PARTICULATE DATA  
MILES CITY AQCR  
Jan. 1973 - Dec. 1973

Station	Minimum	Frequency Distribution (% of values equal to or less than stated one)								Maximum	Arith. Mean	Arith. Std. Dev.	Geo. Mean	Geo. Std. Dev.	Total No. Obs.	Number of Samples Reported Per Month											
		10%	30%	50%	70%	90%	95%	98%	Jan.							Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	
Asay's Res Custer Co. 1040001	7	16	52	89	184	325	361	394	694	139	131	85	3	3	81	9	9	11	9	3	6	7	10	5	6	4	2
LaFlamme Powder River 1240006	2	2	8	15	20	33	44	55	55	16	15	12	3	3	17	4	4	5	4	0	0	0	0	0	0	0	0
Kluever Ranch Rosebud Co. 1360009	3	5	10	23	35	69	84	123	138	32	31	21	3	3	43	5	4	5	5	6	5	1	3	5	4	0	0
Bailey Ranch Rosebud Co. 1360024	1	4	9	16	21	33	49	64	73	19	15	14	2	2	45	5	4	5	5	5	4	5	5	4	3	0	0
Ferris Res. Rosebud Co. 1360025	14	14	16	20	36	146	157	180	180	57	59	36	2	2	15	5	4	2	1	1	2	0	0	0	0	0	0
Hardin MDU Big Horn Co. 0680001	21	31	87	132	160	229	246	255	257	132	68	111	2	2	41	3	4	5	4	4	5	4	5	4	3	0	0
Carlot Ranch Big Horn Co. 0960008	2	4	8	16	22	31	34	35	44	17	11	13	2	2	46	6	4	5	4	4	4	3	5	3	4	3	1

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TABLE 13

Background Dustfall Measurements Taken in  
Southeastern Montana by SDHES  
(Values in Tons/mile<sup>2</sup>)

County	Station	Aver.	1972		Aver.	1973	
			Max.	Samples		Max.	Samples
Rosebud	Lame Deer E 1360003	9.0	16.0	9	7.6	11.8	4
	Birney NE 1360005	9.2	11.6	8	10.6	17.9	4
	Junction Sta. 1360010	18.8	49.6	6	19.3	34.6	7
	Peabody E 1360012	7.2	17.2	9	12.0	34.0	4
	Water Tower 1360014	9.1	29.8	9	5.7	10.3	7
	Forsyth W 1360018	14.4	30.0	9	10.6	17.0	4
	Forsyth E 1360019	16.7	25.5	9	15.9	24.7	4
Big Horn	Ashland Pwr Substa 1360022	7.7	18.4	8	7.8	10.2	4
	Radio Tower 0060002	5.4	14.2	6	4.9	18.1	7
	Lodge Grass E 0060004	17.4	28.5	6	15.2	23.9	4
	Decker Post Off. 0060005	8.1	22.7	6	6.4	21.2	6
	Decker Coal @ Br. 0060007	16.7	39.0	7	24.6	58.1	5
Custer	Carlott Ranch 0060008	-	-	-	10.2	13.1	3
	F&G Off. 0300001	13.6	37.6	9	8.8	13.6	4
	Volburg 0300003	5.0	10.0	9	3.4	7.1	4
	Assay Res. 1040001	22.1	37.8	6	36.9	61.2	4
	Miles City E 1040002	22.5	35.8	9	22.0	33.6	4



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TABLE 13 (Cont.)

County	Station	1972			1973		
		Aver.	Max.	Samples	Aver.	Max.	Samples
Powder River	W Broadus 1240003	33.4	75.5	8	18.9	25.7	4
	Broadus E 1240004	23.5	124.0	9	8.4	15.4	4

TABLE 14  
Background Sulfation Rates Measured in  
Southeastern Montana by SDHES  
(Values in mg SO<sub>3</sub>/100 cm<sup>2</sup>/day)

County	Station	1971			1972			1973		
		Aver.	Max.	Samples	Aver.	Max.	Samples	Aver.	Max.	Samples
Rosebud	Lame Deer W 1360001	-	-	-	0.06	0.13	9	0.04	0.11	4
	Lame Deer N 1360002	-	-	-	0.06	0.13	9	0.07	0.21	5
	Lame Deer E 1360003	-	-	-	0.03	0.10	6	0.02	0.08	4
	Lame Deer LDS Ch- 1360004	-	-	-	0.04	0.13	6	0.05	0.21	5
	Birney NE 1360005	-	-	-	0.04	0.16	8	0.01	0.05	5
	Birney SW 1360006	-	-	-	0.05	0.13	7	0.01	0.05	5
	Ashland E 1360007	-	-	-	0.05	0.10	9	0.03	0.08	3
	Ashland N 1360008	-	-	-	0.08	0.16	8	0.10	0.24	5
	Kluver Ranch 1360009	-	-	-	0.04	0.13	9	0.01	0.06	10
	Junction Sta. 1360010	-	-	-	0.04	0.18	8	0.01	0.06	10
	Colstrip S 1360011	0.02	0.02	3	0.03	0.12	12	0.02	0.06	10
	Peabody E 1360012	-	-	-	0.04	0.07	8	0.01	0.06	10
	West. Ener Off 1360013	0.16	0.16	3	0.14	0.27	11	0.09	0.26	10
	Water Tower 1360014	0.16	0.16	3	0.12	0.23	10	0.04	0.16	10
	Warehouse Substa. 1360015	0.04	0.04	3	0.06	0.16	10	0.02	0.09	10
	Gun Club Sta. 1360016	-	-	-	0.04	0.10	11	0.04	0.10	7
	Oil Stor. Tank 1360017	0.05	0.05	3	0.06	0.13	3	0.02	0.10	10

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TABLE 14 (Cont.)

County	Station	Aver.	1971			Aver.	1972			Aver.	1973		
			Max.	Samples			Max.	Samples			Max.	Samples	
Rosebud	Forsyth W 1360018	-	-	-		0.10	0.24	9		0.03	0.08	5	
	Forsyth E 1360019	-	-	-		0.06	0.15	9		0.03	0.09	5	
	Forsyth Depot 1360020	-	-	-		0.08	0.14	8		0.06	0.15	5	
	Ira Gresons 1360021	-	-	-		0.05	0.17	9		0.02	0.04	5	
	Ashland Pwr. Substa. 1360022	-	-	-		0.06	0.14	8		0.04	0.13	5	
	St. Labre Miss. 1360023	-	-	-		0.04	0.14	8		0.03	0.14	5	
Big Horn	Hardin East 0060001	-	-	-		0.08	0.23	8		0.03	0.11	9	
	Radio Tower 0060002	-	-	-		0.08	0.19	8		0.02	0.12	10	
	Lodge Grass W 0060003	-	-	-		0.04	0.08	7		0.05	0.09	4	
	Lodge Grass E 0060004	-	-	-		0.05	0.13	8		0.08	0.27	5	
	Decker Post Off.- 0060005	-	-	-		0.06	0.14	8		0.01	0.08	12	
	Decker to Birney- Road 0060006	-	-	-		0.03	0.08	7		0.01	0.07	12	
	Decker Coal @ Br- 0060007	-	-	-		0.04	0.15	8		0.01	0.08	12	
	Carlot Ranch 0060008	-	-	-		-	-	-		0.00	0.01	11	
	Hardin MDJ 0680001	-	-	-		0.07	0.28	8		0.02	0.06	10	
Custer	Hardin West 0680002	-	-	-		0.08	0.24	8		0.03	0.08	9	
	F&G Off. 0300001	-	-	-		0.06	0.17	8		0.03	0.09	5	
	Gravel Pit N 0300002	-	-	-		0.06	0.16	8		0.04	0.07	5	
	Volburg 0300003	-	-	-		0.04	0.14	9		0.02	0.06	5	

TABLE 14 (Cont.)

County	Station	Aver.	1971		Aver.	1972		Aver.	1973	
			Max.	Samples		Max.	Samples		Max.	Samples
Custer	Assay Res. 1040001	-	-	-	0.06	0.15	9	0.04	0.11	5
	Miles City E 1040002	-	-	-	0.08	0.21	9	0.04	0.08	5
Powder Riv.	Coalwood 1240001	-	-	-	0.05	0.15	9	0.03	0.10	4
	Ash Creek 1240002	-	-	-	0.05	0.14	9	0.02	0.05	4
	W Broadus 1240003	-	-	-	0.07	0.21	7	0.03	0.13	5
	Broadus E 1240004	-	-	-	0.06	0.16	8	0.03	0.10	5
	Sewage Lagoon 1240005	-	-	-	0.14	0.38	8	0.22	0.80	5
	LaFlamme 1240006	-	-	-	0.05	0.21	7	0.03	0.09	5
	312-212 Junc 1240007	-	-	-	0.04	0.15	9	0.02	0.05	5

TABLE 15

Background Fluoride Levels Measured in  
Southeastern Montana by SDHES  
(Values in ug F<sup>-</sup>/cm<sup>2</sup>/30 days)  
(Na Formate Plates)

County	Station	1972			1973		
		Aver.	Max.	Samples	Aver.	Max.	Samples
Rosebud	Lame Deer W 1360001	0.00	0.00	7	0.02	0.12	5
	Lame Deer N 1360002	0.01	0.10	8	0.00	0.00	5
	Lame Deer E 1360003	0.00	0.00	6	0.00	0.00	5
	Lame Deer LDS Ch. 1360004	-	-	-	0.00	0.00	1
	Birney NE 1360005	0.00	0.00	8	0.03	0.14	5
	Birney SW 1360006	0.00	0.00	8	0.00	0.00	5
	Ashland E 1360007	0.02	0.22	9	0.03	0.14	5
	Ashland N 1360008	0.00	0.00	7	0.02	0.10	5
	Kluver Ranch 1360009	0.02	0.18	8	0.00	0.00	10
	Junction Sta. 1360010	0.00	0.00	8	0.00	0.00	10
	Colstrip S 1360011	0.03	0.15	11	0.01	0.10	10
	Peabody E 1360012	0.00	0.00	8	0.00	0.00	9
	West. Ener. Off. 1360013	0.04	0.22	11	0.00	0.00	10
	Water Tower 1360014	0.05	0.19	10	0.00	0.00	9
	Warehouse Substa. 1360015	0.03	0.17	11	0.00	0.00	10
	Oil Storage Tank 1360017	0.05	0.19	8	0.00	0.00	9
	Forsyth W 1360018	0.00	0.00	8	0.00	0.00	5



TABLE 15 (Cont.)

County	Station	Aver.	1972		Aver.	1973	
			Max.	Samples		Max.	Samples
Rosebud	Forsyth E 1360019	0.00	0.00	7	0.00	0.00	5
	Forsyth Depot 1360020	0.00	0.00	6	0.00	0.00	5
	Ashland Pwr Substa. 1360022	0.01	0.10	7	0.00	0.00	5
Big Horn	Hardin E 0060001	-	-	-	0.00	0.00	1
	Radio Tower 0060002	0.02	0.15	8	0.00	0.00	10
	Lodge Grass W 0060003	0.05	0.20	7	0.00	0.00	4
	Lodge Grass E 0060004	0.02	0.20	8	0.03	0.15	5
	Decker Post Off. 0060005	0.00	0.00	7	0.00	0.00	12
	Decker to Birney Rd. 0060006	0.32	2.24	7	0.00	0.00	11
	Decker Coal @ Br. 0060007	0.02	0.16	8	0.00	0.00	11
	Carlot Ranch 0060008	-	-	-	0.00	0.00	11
Custer	Hardin W 0680002	0.04	0.18	8	0.00	0.00	10
	F&G Office 0300001	0.01	0.10	8	0.00	0.00	5
	Gravel Pit N 0300002	0.00	0.00	7	0.00	0.00	5
	Volburg 0300003	0.00	0.00	8	0.00	0.00	4
Powder River	Assay Res. 1040001	0.00	0.00	8	0.00	0.00	5
	Coalwood 1240001	0.07	0.50	7	0.00	0.00	5
	W Broadus 1240003	0.00	0.00	7	0.02	0.10	5
	Broadus E 1240004	0.02	0.15	8	0.00	0.00	5

TABLE 15 (Cont.)

County	Station	1972			1973		
		Aver.	Max.	Samples	Aver.	Max.	Samples
Powder River	Sewage Lagoon 1240005	0.00	0.00	6	0.00	0.00	5

TABLE 16  
 Background Fluoride Levels Measured in  
 Southeastern Montana by SDHES  
 (Values in ug F<sup>-</sup>/cm<sup>2</sup>/30 days)  
 (Ca Formate Papers)

County	Station	1972			1973		
		Aver.	Max.	Samples	Aver.	Max.	Samples
Rosebud	Lame Deer E 1360003	0.02	0.07	9	0.01	0.01	1
	Kluver Ranch 1360009	0.01	0.04	9	0.01	0.03	10
	Water Tower 1360014	0.07	0.23	9	0.02	0.05	10
	Gun Club Sta. 1360016	0.04	0.06	9	0.04	0.15	10
	Ira Gresons 1360021	0.03	0.08	9	0.02	0.04	5
Big Horn	Hardin MDU 0680001	0.03	0.06	8	0.04	0.11	9
Custer	Miles City E 1040002	0.02	0.03	8	0.03	0.04	5
Powder River	LaFlamme 1240006	0.01	0.02	7	0.01	0.03	5

TABLE 17

## TOTAL SUSPENDED PARTICULATE DATA

## VALUES IN MICROGRAMS PER CUBIC METER

Station	Minimum	Frequency Distribution (% of values equal to or less than stated one)								Maximum	Arith. Mean	Arith. Std. Dev.	Geo. Mean	Geo. Std. Dev.	Total No. Obs.	Number of Samples Reported Per Month*												
		10%	30%	50%	70%	90%	95%	98%	Jan.							Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.		
BN Site Rosebud Co. 1360027	2	6	9	14	22	42	52	73	129	20	18.7	15	1.88	209	20	19	21	20	20	20	20	18	20	20	7	8	15	21
McRae Site Rosebud Co. 1360028	1	5	7	9	14	28	35	42	63	13	10.7	10	1.65	179	20	18	19	20	20	20	12	10	10	8	7	15	20	70

\*Samplers operated from Nov. 73 through June 75 at the McRae site and Nov. 73 through Aug. 75 at the BN site.

Figure 11

## Total Suspended Particulate Frequency Distribution

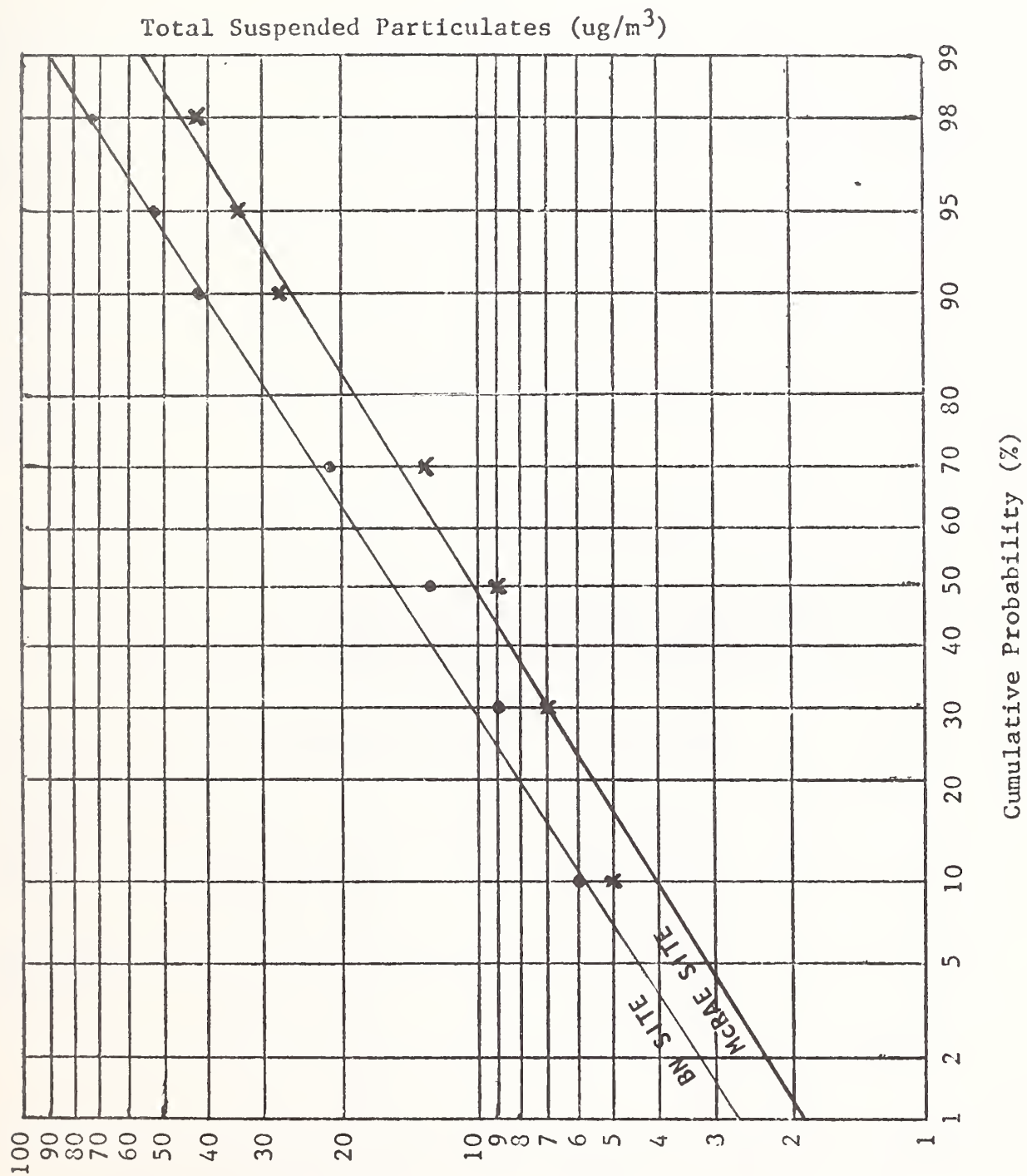




TABLE 18

Settleable Particulates (Dustfall Jar)  
 Values in Tons per Square Mile  
 Operational Period: Nov. 73 - Nov. 74

Sampler Location	Average Value	Max. Value	No. of Samples
Rosebud Co. BN Site 1360027	4.4	11.4	9
Rosebud Co. McRae Site 1360028	3.3	6.7	10
Rosebud Co. Halfway Site 1360029	4.1	6.9	7
Rosebud Co. Antenna Hill 1360030	7.3	25.0	9

TABLE 19

Arithmetic Average Particulate Sizing Data  
 Cascade Impactor  
 Period: December, 1973 - August, 1975

Particle Size (Microns)	Values in micrograms per cubic meter	
	BN Site	McRae Site
7.0 and >	4.08 (23.3)*	2.80 (20.6)*
3.3 - 7.0	2.97 (16.9)	2.11 (15.5)
2.0 - 3.3	2.07 (11.8)	1.52 (11.2)
1.1 - 2.0	1.54 (8.7)	1.24 (9.1)
Submicron	6.85 (39.1)	5.86 (43.3)
TOTAL	17.51	13.53
No. of Samples	104	89

\*Values in parentheses are average percentages of the total particulate load.

TABLE 20

Fluorides in the Air (Na Formate Plates)  
 Values in micrograms fluoride per square centimeter per 30 days  
 Operational Period: Nov. 1973 - Aug. 1975

Sampler Location	Average Value	Max. Value	No. of Samples
Rosebud Co. BN Site 1360027	0.017	0.13	19
Rosebud Co. McRae Site 1360028	0.008	0.11	21
Rosebud Co. Halfway Site 1360029	0.014	0.11	18
Rosebud Co. Antenna Hill 1360030	0.004	0.05	20

TABLE 21

Fluorides in the Air (Ca Formate Papers)  
 Values in micrograms fluoride per square centimeter per 30 days  
 Operational Period: Nov. 1973 - Aug. 1975

Sampler Location	Average Value	Max. Value	No. of Samples
Rosebud Co. BN Site 1360027	0.021	0.23	19
Rosebud Co. McRae Site 1360028	0.012	0.09	19

TABLE 22

Sulfation Rate (Lead Plate)  
 Values in milligrams SO<sub>3</sub> per 100 square centimeters per day  
 Operational Period: Nov. 73 - Aug. 75

Sampler Location	Average Value	Max. Value	No. of Samples
Rosebud Co. BN Site 1360027	0.018	0.090	18
Rosebud Co. McRae Site 1360028	0.005	0.030	20
Rosebud Co. Halfway Site 1360029	0.013	0.070	19
Rosebud Co. Antenna Hill 1360030	0.013	0.060	19
Rosebud Co. Sewage Lagoon 1360031	0.073	0.350	20
Rosebud Co. Colstrip West 1360032	0.018	0.070	16

TABLE 23

Sulfur Dioxide (Gas Bubbler)  
 Values in parts per million SO<sub>2</sub>

	Rosebud Co. BN Site 1360027 11/73 - 8/75	Rosebud Co. McRae Site 1360028 11/73 - 5/75
Geometric Mean	0.0000	0.0000
Arithmetic Mean	0.0001	0.0001
Max. 24-hour Value	0.0010	0.0010
No. Samples Taken*	159	143

\*Samplers were run for 72 hours.

TABLE 24

Nitrogen Dioxide (Gas Bubbler)  
Values in parts per million NO<sub>2</sub>

	Rosebud County BN Site 1360027 11/73 - 8/75	Rosebud County McRae Site 1360028 11/73 - 5/75
Geometric Mean	0.0011	0.0007
Arithmetic Mean	0.0015	0.0013
Maximum 24-Hour Value	0.0060	0.0050
No. Samples Taken*	150	143

\*Samplers were run for 72 hours

TABLE 25

Continuous Monitor Data  
McRae Site  
Values in Parts Per Million

Pollutant	Arith. Aver.	Max. 1-hr Value	No. Days Data	No. Samples Taken	Operational Period
Sulfur Dioxide	0.00	0.00	470	9942	11/73-6/75
Carbon Monoxide	0.00	0.00	422	8635	11/73-5/75
Ozone	0.03	0.08	380	7879	12/73-5/75
Nitric Oxide	0.00	0.00	345	7961	12/73-2/75
Nitrogen Dioxide	0.00	0.00	431	9937	12/73-5/75
Oxides of Nitrogen	0.00	0.00	346	7996	12/73-2/75

TABLE 26

Continuous Monitor Data  
BN Site

Pollutant	Arith. Aver.	Max. 1-hr Value	No. Days Data	No. Samples Taken	Operational Period
Ozone	0.03	0.06	46	925	7/75-8/75
Sulfur Dioxide	0.00	0.01	61	1319	7/75-8/75
Nitrogen Dioxide	0.00	0.00	34	769	6/75-8/75

TABLE 27

Membrane Filters (Trace Element Analysis)  
 Average Values in  $\mu\text{g}/\text{m}^3$   
 Operational Period: Nov. 1973 - June 1974

Element	BN Site	McRae Site
Antimony	<0.002	<0.002
Tin	<0.02	<0.02
Vanadium	<0.005	<0.005
Beryllium	<0.0001	<0.0001
Chromium	0.001	0.001
Lead	0.0156	0.127
Cadmium	0.00004	0.00006
Strontium	0.00045	0.00033
Silver	<0.001	<0.001
Manganese	0.0042	0.0039
Zinc	0.0402	0.0493
Copper	0.008	0.008
Iron	0.151	0.123
Mercury	<0.0002	<0.0002
Calcium	0.212	0.115
Magnesium	0.047	0.047
Lithium	None Detected	None Detected
Sodium	0.064	0.064
Potassium	0.049	0.040
Selenium	<0.001	<0.001
Average No. Samples	41	41

TABLE 28

Radiation Measurements  
McRae Site  
1974

	Ultra-Violet* Radiation (Photometer)	Solar Radiation+ (Quantum Sensor) Sampler I	Solar Radiation+ (Quantum Sensor) Sampler II
10 A.M. Arith. Aver. (1-hr)	18	498	678
Std. Dev.	8	235	324
Max. Value	77	1972	2369
Min. Value	0	0	0
No. Readings	233	232	232
12 Noon Arith. Aver. (1-hr)	31	822	1105
Std. Dev.	13	343	476
Max. Value	78	1870	2610
Min. Value	0	0	0
No. Readings	231	230	230
2 P.M. Arith. Aver. (1-hr)	34	873	1207
Std. Dev.	13	332	482
Max. Value	79	1972	2690
Min. Value	0	0	0
No. Readings	230	220	229
4 P.M. Arith. Aver. (1-hr)	27	738	990
Std. Dev.	10	270	368
Max. Value	73	1802	2449
Min. Value	0	0	0
No. Readings	230	228	228

\*Values in millicalories per square centimeter per minute

+Values in microeinsteins per square meter per second



TABLE 29

Visibility Measurements for 1974  
Values in Linear Miles

	BN Site	McRae Site
Arithmetic Average (Year)	351.9	252.4
" (Jan)	530.9	314.9
" (Feb)	535.6	273.8
" (Mar)	383.9	262.6
" (Apr)	267.4	210.4
" (May)	162.0	222.4
" (June)	185.9	186.5
" (July)	150.2 <sup>+</sup>	105.7 <sup>+</sup>
" (Aug)	107.5 <sup>+</sup>	-
" (Sept)	-	1424
" (Oct)	45.6 <sup>+</sup>	195.4
" (Nov)	218.8	234.3
" (Dec)	511.5	501.0
Min. 1-hr/ Corres. relative humidity*	3.1/100	11.2/99
Min. 3-hr/ Corres. relative humidity*	3.2/100	16.7/99
Min. 24-hr/ Corres. relative humidity*	12.2/-	35.4/80
Total Readings Taken	6095	6763

\*RH data from McRae Site

<sup>+</sup>Only partial month of data

TABLE 30  
Stand Data Summary for Tongue River Riparian Communities

Item	Plot		Basal		Cover		Relative Frequency		Relative Dominance		Relative Density		Importance Value	
	Frequency Percent	Density Stems/acre	Area Ft <sup>2</sup> /acre	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Value	Percent
Tree size class:														
Populus deltoides	55	177.23	106.20	--	24.4	60.90	29.3	38.20						
Fraxinus pennsylvanica	55	120.84	32.60	--	24.4	18.70	20.0	21.03						
Acer negundo	50	84.59	23.00	--	22.2	13.20	14.0	16.16						
Prunus virginiana	20	136.59	2.70	--	8.9	1.50	22.7	11.03						
Crataegus succulenta	10	16.11	0.23	--	4.4	0.13	2.7	2.41						
Salix spp.	30	66.46	9.52 <sup>^</sup>	--	13.4	5.45	11.0	9.92						
Juniperus scopulorum	5	2.01	0.13	--	2.2	0.07	0.3	0.86						
TOTAL	225	604.19	174.38	--	100.00	100.00	100.00	100.00						
Shrub size class:														
Populus deltoides	5	28.20	3.05	--	5.88	4.17	7.36	5.80						
Fraxinus pennsylvanica	15	40.28	35.10	--	17.64	43.11	10.52	25.42						
Acer negundo	20	10.07	14.90	--	23.52	20.43	2.63	15.52						
Prunus virginiana	20	78.54	4.98	--	11.76	6.81	20.52	13.03						
Crataegus succulenta	5	4.03	0.44	--	5.88	0.59	1.05	2.51						
Salix spp.	30	221.54	14.49	--	35.29	19.86	57.89	37.68						
TOTAL	85	382.66	72.94	--	100.00	100.00	100.00	100.00						

TABLE 30 (continued)  
Stand Data Summary for Tongue River Riparian Communities

Item	Plot		Basal Area Ft <sup>2</sup> /acre	Cover Percent	Relative Frequency		Relative Dominance		Relative Importance	
	Frequency Percent	Density Stems/acre			Percent	Percent	Percent	Percent	Density Percent	Value Percent
Tree seedling size class:										
Populus deltoides	5	50.60	0.0910	--	9.10	15.50	3.84	9.48		
Fraxinus pennsylvanicus	34	1012.00	0.364	--	63.63	62.08	76.92	67.54		
Acer negundo	10	101.20	0.1012	--	18.18	17.24	7.69	14.37		
Salix spp.	5	151.80	0.0303	--	9.10	5.16	11.53	8.60		
TOTAL	55	1315.16	0.5868	--	100.00	100.00	100.00	100.00		
Shrub size class:										
Rosa arkansana	45	5110.60	3.2890	--	42.85	65.26	44.69	50.93		
Symphoricarpos oxidentalis	40	5060.00	1.0120	--	38.09	20.08	44.24	34.14		
Ribes spp.	15	1163.80	0.5566	--	14.28	11.04	10.17	11.81		
Cornus stolonifera	5	101.20	0.1821	--	4.76	3.61	0.88	3.08		
TOTAL	105.00	11435.60	5.0397	--	100.00	100.00	100.00	100.00		

TABLE 30 (continued)  
Stand Data Summary for Tongue River Riparian Communities\*

Item	Plot		Basal Area Ft <sup>2</sup> /acre	Cover Percent	Relative Frequency Percent	Relative Dom nance Percent	Relative Density Percent	Importance Value Percent
	Frequency Percent	Density Stems/acre						
Grasses, Forbs & Low Shrubs:								
Taraxacum officinale	25	--	--	3.60	10.20	8.44	--	9.32
Poa spp.	25	--	--	8.75	10.20	20.51	--	15.35
Achillea millefolium	5	--	--	0.10	2.04	0.23	--	1.15
Melilotus officinalis	15	--	--	1.10	6.12	2.57	--	4.34
Phalaris arundinacea	40	--	--	7.35	16.32	17.23	--	16.77
Arctium lappa	25	--	--	6.50	10.20	15.24	--	12.72
Chenopodium album	10	--	--	0.80	4.08	1.87	--	2.97
Galium spp.	30	--	--	5.65	12.24	13.24	--	12.74
Bromus spp	10	--	--	2.50	4.08	5.86	--	4.97
Sisymbrium altissimum	5	--	--	1.25	2.04	2.93	--	2.48
Urtica dioica	5	--	--	0.10	2.04	0.23	--	1.13
Mentha arvensis	5	--	--	0.05	2.04	0.11	--	1.07
Stipa comata	5	--	--	0.05	2.04	0.11	--	1.07
Smilacina stellata	15	--	--	0.85	6.12	1.99	--	4.06
Cirsium spp.	10	--	--	0.90	4.08	2.11	--	3.09
Asclepias viridiflora	5	--	--	0.10	2.04	0.23	--	1.13
Rhus radicans	10	--	--	3.00	4.08	7.03	--	5.55

\*Species less than 1% cover/plot were not included in the identification, listing & computation of these values.

Table 31

Tree Heights of Riparian Constituents from the Tongue River\*

Species	Avg. Ht.	# Determinations	SD
<i>Populus deltoides</i>	56.2	26	26.0
<i>Acer negundo</i>	33.6	14	4.2
<i>Fraxinus pennsylvanica</i>	38.84	13	8.5
<i>Salix</i> spp.	29.0	8	12.82
<i>Prunus virginiana</i>	21.2	4	2.2
<i>Crataegus succulenta</i>	22.7	3	1.88

\*These determinations were made using a Suunto clinometer

TABLE 32

AGE OF SELECTED OVERSTORY AND UNDERSTORY TREES  
FROM TONGUE RIVER PLANT COMMUNITY\*

Species	Site	Diameter (inches)	Age
<i>Populus deltoides</i>	TR 1	10.0	41
" "	TR 1	9.0	36
" "	TR 3	10.5	56
" "	TR 11	7.0	18
<i>Salix</i>	TR 9	8.5	36
"	TR 16	7.5	42
<i>Fraxinus pennsylvanica</i>	TR 3	3.5	26
" "	TR 7	6.5	53
" "	TR 13	6.5	48
" "	TR 15	5.5	31
" "	TR 16	5.0	42
<i>Acer negundo</i>	TR 5	6.0	25
" "	TR 7	2.7	17
" "	TR 16	6.4	27
<i>Prunus virginiana</i>	TR 6	3.0	27
" "	TR 14	2.5	19

\*These cores were taken using a 12" Jim Gem stainless steel borer.



Table 33

Partial List of Plants Found in the Riparian Communities of the  
Tongue River in the Vicinity of Ashland, Montana

	<u>Scientific Name</u>	<u>Common Name</u>
Trees:	<i>Acer negundo</i>	Boxelder
	<i>Crataegus succulenta</i>	Fl <sup>~</sup> shy hawthorn
	<i>Fraxinus pennsylvanica</i>	Green ash
	<i>Juniperus scopulorum</i>	Rocky Mtn. juniper
	<i>Populus deltoides</i>	Plains cottonwood
	<i>Prunus virginiana</i>	Chokecherry
	<i>Salix</i> spp.	Willow
Shrubs:	<i>Cornus stolonifera</i>	Dogwood
	<i>Rhus radicans</i>	Poison ivy
	<i>Ribes</i> supp.	Currant, gooseberry
	<i>Rosa arkansana</i>	Prairie rose
	<i>Symphoricarpos occidentalis</i>	Snowberry
Grasses & Forbs:	<i>Achillea millefolium</i>	Yarrow
	<i>Arctium lappa</i>	Budrock
	<i>Asclepias viridiflora</i>	Milkweed
	<i>Bromus</i> spp.	Cheatgrass
	<i>Chenopodium album</i>	Lambsquarters
	<i>Cirsium</i> spp.	Thistle
	<i>Galium</i> spp.	Bedstraw
	<i>Melilotus officinalis</i>	Yellow clover
	<i>Mentha arvensis</i>	Field mint
	<i>Phalaris arundinacea</i>	Reedgrass
	<i>Poa.</i> spp.	Bluegrass
	<i>Sisymbrium altissimum</i>	Tumblemustard
	<i>Smilacina stellate</i>	False Solomon's seal
	<i>Stipa comata</i>	Needle-and-thread
	<i>Taraxacum officinale</i>	Dandelion
	<i>Urtica dioica</i>	Stinging nettle

TABLE 34

## COLSTRIP VEGETATION SAMPLES

Site	Box- Elder F ppm	Hawthorn F ppm	Green ash F ppm	Cotton- wood F ppm	Choke- cherry F ppm	Golden Currant F ppm	Prairie rose F ppm	Snowberry F ppm	Willow F ppm	PLOT	
										SD	Mean
N1	<0.1	-	-	-	-	-	<0.1	<0.1	<0.1	0	0.05
N2	-	-	-	<0.1	-	-	-	<0.1	-	0	0.05
N3	<0.1	-	-	<0.1	-	-	-	<0.1	-	0	0.05
NE1	-	-	<0.1	-	<0.1	-	1.0	1.0	-	0	0.05
NE2	-	-	<0.1	<0.1	2.0	-	<0.1	<0.1	-	0.55	0.52
NE3	1.0	-	<0.1	1.0	-	-	<0.1	<0.1	-	0.87	0.44
E1	-	-	<0.1	-	1.0	<0.1	2.0	<0.1	-	0.81	0.82
E2	7.0	-	<0.1	-	3.0	<0.1	2.0	<0.1	-	2.86	2.62
E3	-	-	<0.1	-	TONGUE RIVER	-	<0.1	3.0	-	2.86	2.62
SE1	-	-	2.0	<0.1	<0.1	-	<0.1	<0.1	-	0.80	0.38
SE2	3.0	-	<0.1	<0.1	-	-	<0.1	<0.1	-	2.14	1.37
SE3	-	-	-	-	TONGUE RIVER	<0.1	-	-	5.0	-	-
S1	<0.1	-	3.0	-	-	-	-	<0.1	-	-	-
S2	<0.1	-	-	<0.1	<0.1	<0.1	-	<0.1	-	-	-
S3	-	3.0	<0.1	-	-	-	2.0	<0.1	-	1.48	0.79
SW1	-	-	-	-	-	-	1.0	<0.1	-	0.87	0.44
SW2	2.0	-	-	<0.1	-	-	<0.1	<0.1	-	1.39	1.02
SW3	<0.1	-	-	<0.1	<0.1	-	<0.1	<0.1	-	0.0	0.05
W1	1.0	-	-	<0.1	4.0	-	<0.1	<0.1	-	0.87	0.44
W2	<0.1	-	-	-	4.0	<0.1	<0.1	1.0	-	1.71	1.03
W3	<0.1	1.0	1.0	<0.1	-	<0.1	8.0	<0.1	-	3.42	2.52
NW1	-	3.0	3.0	3.0	-	<0.1	2.0	1.0	-	0.81	0.82
NW2	-	1.0	1.0	-	-	-	2.0	1.0	-	0.81	0.82
NW3	-	-	-	1.0	-	-	<0.1	2.0	-	0.97	1.02
S4	-	-	-	1.0	-	-	<0.1	<0.1	<0.1	0.97	0.54
SW4	-	<0.1	<0.1	<0.1	4.0	-	1.0	<0.1	1.0	0.55	0.68
	-	-	-	<0.1	<0.1	-	3	<0.1	<0.1	2.04	2.26
	-	-	-	-	<0.1	-	-	<0.1	<0.1	1.20	0.54
SPECIES											
SD	2.07	1.14	0.87	1.78	0.0	1.86	0.76	2.23			
Mean	1.20	0.80	0.47	1.66	0.5	1.22	0.43	1.69			

TABLE 35

## TONGUE RIVER SAMPLES

Site	Box- Elder F ppm	Hawthorn F ppm	Green ash F ppm	Cotton- wood F ppm	Choke- cherry F ppm	Golden Currant F ppm	Prairie rose F ppm	Snowberry F ppm	Willow F ppm	PLOT	
										SD	Mean
TR1	-	-	-	<0.1	-	-	-	1.0	-	0.67	0.52
TR2	-	-	-	<0.1	-	-	1.0	-	-	0.67	0.52
TR3	-	-	<0.1	<0.1	-	-	<0.1	6.0	-	2.98	1.54
TR4	<0.1	-	<0.1	<0.1	-	-	-	<0.1	-	0.0	0.05
TR5	<0.1	-	-	<0.1	-	-	-	-	-	0.0	0.05
TR6	-	2.0	-	-	<0.1	-	<0.1	6.0	-	2.80	2.02
TR7	<0.1	-	<0.1	-	-	-	<0.1	-	-	0.0	0.05
TR8	<0.1	-	-	-	-	-	-	-	1.0	0.67	0.52
TR9	4.0	-	<0.1	-	-	-	<0.1	-	2.0	1.88	1.52
TR10	2.0	-	1.0	<0.1	-	-	-	-	7.0	3.10	2.51
TR11	-	-	-	<0.1	-	-	-	-	7.0	4.91	3.52
TR12	-	-	-	<0.1	-	-	-	-	2.0	1.37	1.02
TR13	-	-	<0.1	<0.1	<0.1	-	<0.1	<0.1	-	0.0	0.05
TR14	-	-	-	-	<0.1	-	<0.1	1.0	-	0.0	0.05
TR15	-	<0.1	<0.1	-	15.0	<0.1	<0.1	-	-	6.68	3.04
TR16	4.0	-	<0.1	-	-	-	-	-	<0.1	2.28	1.37
TR17	9.0	-	1.0	<0.1	-	-	<0.1	<0.1	<0.1	3.60	1.70
TR18	-	-	<0.1	<0.1	-	-	<0.1	7.0	<0.1	3.11	1.44
TR19	<0.1	-	-	-	-	-	<0.1	<0.1	-	0.0	0.05
TR20	3.0	-	2.0	<0.1	-	-	<0.1	<0.1	<0.1	1.30	0.87
SPECIES											
SD	2.9'	1.38	0.65	0.0	7.47	0.05	0.29	2.86	2.87		
Mean	2.22	1.02	0.40	0.05	3.78	0.05	0.14	1.94	2.13		

TABLE 36

## Colstrip Soil Sample Analyses Data

Site	**Na*	K*	Ca*	Mg*	Sr	Li	Se	Zn	Fe*	Cr	Mn	Cu	As	Hg	Sn	Sb	V	Ag	Be	Pb	Cd	F
N1 T	7.7	17	36	6	32	<.25		63	21	26	270	<25	2.8	.09	<10	<3	20	<0.5	<0.2	<0.5	<0.05	334
B	7.8	22	26	10	50	22	<.6		22	43	160	13	1.8	.09	<10	<3	23	<0.3	<0.2	<0.5	<0.05	364
N2 T	11	16	32	11	56	<.25		57	19	25	400	<25	3.8	.26	<10	<3	10	<0.5	<0.2	<0.5	<0.05	353
B	9	17	60	15	120	<50	<0.5	60	20		410	<25	2.4	.06	<10	<5	9	<0.2	<0.1	<0.5	<0.1	364
N3 T	9	17	9.5	6	155	<50	<0.5	58	21	49	590	<25	1.6	.13	<10	<5	22	<0.2	<0.1	<0.5	<0.1	257
B																						
N4 T	22	20	16	7.3	280	19	<0.6		31	56	300	20	2.5	<.09	<10	<3	93	<.03	<0.2	<0.5	<0.05	364
B	13	16	12.5	5.5	225	<50	<0.5	51		48	390	<25	0.8	.52	<10	<5	25	<0.2	<0.1	<0.5	<0.1	250
NE1 T	7.8	21	30	9.7	70	17	<0.6		24	46	310	15	4.8	<.09	<10	<3	43	<0.3	<0.2	<0.5	<0.05	671
B	7.5	18	60	12	130	<50	<0.5	56	13		390	<25	0.5	0.6	<10	<5	3	<0.2	<0.1	<0.5	<0.1	834
NE2 T	12.5	15	47	15	110	<.25		56	21	35	1000	<25	33.2	.09	<10	<3	5	<0.5	<0.2	<0.5	<0.05	228
B	13	19				19	<0.6		26	42	370	14	2.5		<10	<3	60	<0.3	<0.2	<0.5	<0.05	325
NE3 T	11	19	14	9.2	100	17	<0.6		29	44	350	19	2.4		<10	<3	63	<0.3	<0.2	<0.5	<0.05	649
B	11	21	56	14	140	22	<0.6		28	44	450	22	2.6	<.09	<10	<3	15	<0.3	<0.2	<0.5	<0.05	363
NE4 T	6.4	16	3.9	4.3	95	<50	<0.5	48	16	28	340	<25	2.2	<.06	<10	<5	12	<0.2	<0.1	<0.5	<0.1	646
B	15	21	7.3	7.1	140	17	<0.6		23	44	240	24	4.8	<.09	<10	<3	43	<0.3	<0.2	<0.5	<0.05	271
E 1 T																						
B	7.2	20	21	13.5	120	<50	<0.5	45	22	39	600	<25	4.2	<.06	<10	<5	12	<0.2	<0.1	<0.5	<0.1	383
E 2 T	11	20	42	12	70	19	<0.6		24	33	1.80	13	2.8	<.09	<10	<3	23	<0.3	<0.2	<0.5	<.05	353
B	9.5	20	44.5	13	85	<50	<0.5	46	19	26	260	<25	2.4	.06	<10	<5	3	<0.2	<0.1	<0.5	<0.1	397
E 3 T	8.9	9.2	15.5	11.5	120	<50	<0.5	49	16		340	<25	2.1	.06	<10	<5	9	<0.2	<0.1	<0.5	<0.1	603
B	12	20	38	17	80	22	<0.6		23	36	210	16	4.7	.10	<10	<3	8	<0.3	<0.2	<0.5	<0.05	320
E 4 T	8.2	20	31	14	71	<.25		72	26	47	530	<25	0.6	<.09	<10	<3	35	<0.5	<0.2	<0.5	<0.05	606
B	7.1	21	46.5	1.5	90	<50	<0.5	82	28		470	<25	1.4	20	<10	<5	25	<0.2	<0.1	<0.5	<0.1	565

\* = ppm  $\times 10^{-3}$ \*\*T = A<sub>1</sub> Horizon  
B = B<sub>2</sub> Horizon

TABLE 36 (Continued)

## Colstrip Soil Sample Analyses Data

Site**	NA*	K*	Ca*	Mg*	Sr	Li	Se	Zn	Fe*	Cr	Mn	Cu	As	Hg	Sn	Sb	V	Ag	Be	Pb	Cd	F
					ppm	ppm	ppm	ppm			ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
SE 1 T																						
B	9.4	17	58	19	63	<0.25	-	48	22	37	340	<25	3.5	.09	<10	-	5	-	<0.2	<.05	<0.05	404
SE 2 T	7.8	18	43	19	60	<0.25	-	71	22	38	390	<25	4.2	<.09	<10	<3	45	<0.5	<0.2	<0.5	<0.05	540
B	8.1	13	49	21	60	<0.25	-	72	22	37	410	<25	6.7	.26	<10	<3	5	<0.5	<0.2	<0.5	<0.05	459
SE 3 T	9.3	20	89	10	120	<0.25	-	131	34	62	770	<25	8.3	.18	<10	<3	100	<0.5	<0.2	<0.5	<0.05	507
B	11	25	22	19	160	30	<0.6	-	38	73	410	50	8.2	<.09	<10	<3	48	<0.3	<0.2	<0.5	<0.05	506
SE 4 T	6.4	23	42	17	120	27	<0.6	-	35	57	290	40	3.3	.26	<10	<3	78	<0.3	<0.2	<0.5	<0.05	539
B	6.4	23	42	26	120	30	<0.6	-	34	65	530	48	3.3	<.09	10	<3	78	<0.3	<0.2	<0.5	<0.05	623
S 1 T	6.7	12	23	10	32	<.25	-	65	25	41	1000	<25	4.6	<.09	<10	<3	45	0.5	-	<0.5	<0.05	547
B	3.6	15	100	17.5	135	<50	<0.5	64	20	-	330	<25	1.3	.46	<10	<5	9	<0.2	<0.1	<0.5	<0.1	515
S 2 T	6	15	47.5	17	100	<50	<0.5	57	13	-	300	<25	2.7	.13	<10	<5	<3	<0.2	<0.1	<0.5	<0.1	334
B	8.5	17	60	21	105	<50	<0.5	61	20	-	360	<25	1.3	.20	<10	<5	3	<0.2	<0.1	<0.5	<0.1	372
S 3 T	8.5	18	66	8	48	<.25	-	45	20	33	370	<25	2.2	.35	<10	<3	25	<0.5	<0.2	<0.5	<0.05	327
B	10	20	12	11	55	22	<0.6	-	23	40	180	16	1.7	.09	<10	<3	33	<0.3	<0.2	<0.5	<0.05	342
S 4 T	7.6	20	48	20.5	120	<50	<0.5	61	20	-	340	<25	3.1	.06	<10	<5	22	<0.2	<0.1	<0.5	<0.1	339
B	8.8	18	46	16	52	<.25	-	56	20	38	360	<25	1.6	<.09	<10	<3	10	<0.5	<0.2	<0.5	<0.05	771
SW 1 T	7.1	18	41.5	20	105	<50	<0.5	62	23	-	360	<25	3.8	.06	<10	<5	16	<0.2	<0.1	<0.5	<0.1	427
B	8.4	19	17	10	75	<.25	-	76	26	41	620	<25	5.0	.18	<10	<3	30	<0.5	<0.2	<0.5	<0.05	342
SW 2 T																						
B																						
SW 3 T	9.8	17	22	12	20	<0.25	-	-	20	35	380	<25	4.0	.20	<10	<3	30	<0.5	-	<0.5	<0.05	507
B	8.2	16	37	10	40	<0.25	-	56	21	32	550	<25	5.2	-	40	<3	25	<0.5	-	<0.5	<0.05	360
SW 4 T																						
B																						

\*= ppm x 1000

\*\* T = A<sub>1</sub> Horizon  
B = B<sub>2</sub> Horizon



TABLE 36 (Continued)

Colstrip Soil Sample Analyses Data

Site**	Na*	K*	Ca*	Mg*	Sr	Li	Se	Zn	Fe*	Cr	Mn	Cu	As	Pb	Sn	Sb	V	Ag	Be	Pb	Cd	F
W 1 T	B 7.6	24.0	4.8	7.0	40	<50	<0.5	71	25	-	580	<25	4.4	.52	<10	<5	6	<0.2	<0.1	<0.5	<0.1	394
W 2 T	B 5.6	-	32	18	70	<50	<0.5	50	20	46	350	<25	1.5	.06	<10	<5	6	<0.2	<0.1	<0.5	<0.1	488
W 3 T	B 6.9	19.0	20.5	13	110	<50	<0.5	45	20	37	360	<25	1.3	<.06	<10	<5	6	<0.2	<0.1	<0.5	<0.1	367
B 8.1	19.0	45	12	125	<50	<0.5	<0.5	71	25	-	330	<25	1.8	.06	<10	<5	6	<0.2	<0.1	<0.5	<0.1	394
W 4 T	B 5.9	15.0	40	13.5	175	<50	<0.5	62	25	52	350	<25	3.4	.06	<10	<5	22	<0.2	<0.1	<0.5	<0.1	378
B 7.7	18	85	20	240	25	<.6	-	-	31	60	240	26	5.1	-	<10	<3	8	<.3	<.2	<0.5	<0.05	507
NW 1 T	B 8.8	18.0	47	14	71	<.25	<1	50	20	29	320	<25	5.6	.35	<10	<3	10	<0.5	<0.2	<0.5	<0.05	320
B 8.8	18.0	55	16	100	<50	<0.5	<0.5	49	18	31	290	<25	0.5	.13	<10	<5	3	<0.2	<0.1	<0.5	<0.1	323
NW 2 T	B 6.5	18.0	16	10	135	<50	<0.5	57	19	39	600	<25	4.4	<.06	<10	<5	22	<0.2	<0.1	<0.5	<0.1	393
B 7.2	17.0	26	11.5	175	<50	<0.5	<0.5	78	36	-	580	<25	2.4	.06	<10	<5	25	<0.2	<0.1	<0.5	<0.1	353
NW 3 T	B 10.0	17.0	80.0	13.5	130	<50	<0.5	56	18	-	650	<25	0.7	.06	<10	<5	3	<0.2	<0.1	<0.5	<0.1	394
NW 4 T	B 10	16	9.5	6	105	<50	<0.5	49	18	28	350	<25	1.0	.13	<10	<5	16	<0.2	<0.1	<0.5	<0.1	345
B 4	23	20	11	150	25	<0.6	-	-	31	47	300	21	3.9	.09	<10	<3	80	<.3	<.2	<.5	<.05	485
NW 5 T	-	-	14.5	6	300	<50	<0.5	52	21	44	420	<25	0.6	.13	<10	<5	20	<0.2	<0.1	<0.5	<0.1	217
B 14.0	16.0	12.5	5.5	165	<50	<0.5	<0.5	73	26	-	450	<25	4.2	.33	<10	<5	25	<0.2	<0.1	<0.5	<0.1	284
* = ppm x1000																						
X	9.23	18.5	22.1	12.7	109.5	17.6	0.3	60.7	23.3	41.8	411	15.6	3.1	.13	5.0	2.0	25.5	.15	.07	0.25	0.03	484.43
SD	3.04	2.6	36.8	5.13	58.2	10.94	0.04	15.1	5.5	10.9	170	8.1	1.8	.12	0	.5	24.1	.06	.02	0	0.01	274.99

\*\*T = A<sub>1</sub> Horizon  
B = B<sub>2</sub> Horizon



TABLE 37

## pH of Soil Samples From Colstrip

Site	Horizon A <sub>1</sub> pH	Mean depth (in.)	Site	Horizon B <sub>2</sub> pH	Mean depth (in.)
N1	8.3	1.5	N1	8.9	4.5
N2	8.5	1.5	N2	8.8	4.5
N3	6.8	1.5	N3	8.1	4.5
NE1	8.4	1.5	NE1	8.7	4.5
NE2	8.5	1.5	NE2	8.8	4.5
NE3	8.4	1.5	NE3	8.8	4.5
NE4	--		NE4	7.4	4.5
E1	--		E1	8.6	4.5
E2	8.4	1.5	E2	8.9	4.5
E3	8.4	1.5	E3	8.9	4.5
E4	8.4	1.5	E4	8.6	4.5
SE2	--		SE2	8.6	4.5
SE3	--		SE3	8.0	4.5
S1	8.6	1.5	S1	8.6	4.5
S4	8.5	1.5	S4	8.9	4.5
SW1	8.4	1.5	SW1	8.6	4.5
SW3	8.7	1.5	SW3	--	
W1	8.7	1.5	W1	7.9	4.5
W2	8.4	1.5	W2	8.6	4.5
W3	8.7	1.5	W3	8.7	4.5
W4	8.5	1.5	W4	8.8	4.5
NW1	7.9	1.5	NW1	8.9	4.5
NW2	8.5	1.5	NW2	8.6	4.5
NW3	8.1	1.5	NW3	8.9	4.5
NW4	8.0	1.5	NW4	8.7	4.5

 $\bar{x} = 8.4^*$  $\bar{x} = 8.6^*$ 

\*significant at 0.025



